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# Assessment of Haddock on Eastern Georges Bank

by

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## ABSTRACT

Landings of haddock from eastern Georges Bank, from the early 1980s to 1993, fluctuated around 5,000 tons. Under restrictive management measures, the 1994 and 1995 landings declined to 2561t and 2164t respectively. The 1995 fisheries were largely supported by the 1991 and 1992 year-classes which comprised about 75% of the landed weight. Survey trends indicate a decline of adult abundance since about 1990 to almost the lowest levels observed but an increase has been observed since 1993. Indices for the 1992 year-class suggest that it is the strongest since the 1983, 1985 and 1987 year-classes.

The adaptive framework was used to calibrate the sequential population analysis to the research survey trends. Biomass for ages 3 and older increased to about 23,000t at the beginning of 1996 after declining to below 10,000t, approaching the historic low. The abundance of the1992 year-class was estimated at about 17 million, comparable to the 1983, 1985 and 1987 year-classes. The fishing mortality rate for ages 4 and older decreased to 0.16 in 1995 from about 0.6 in 1992 and 1993, the highest observed since 1971.

A projected yield of about 6,800t in 1996 would correspond to the $F_{0.1}$= 0.28 fishing mortality rate and result in a marginal increase of about 1,000t for ages 3 and older biomass. Roughly half the projected yield in 1996 and the biomass in 1997 though, was attributed to the 1992 year-class. A risk analysis showed that a catch of 5,000t in 1996 would ensure that the $F_{0.1}$ fishing mortality rate was not exceeded and would enhance the probability that the biomass would increase between 1996 and 1997.



**Résumé**

Du début des années 1980 à 1993, les débarquements d'aiglefin en provenance de la partie est du banc Georges ont été de l'ordre de 5 000 t. L'application de mesures restrictives en 1994 et 1995 ont fait tomber cette valeur à, respectivement, 2561 t et 2164 t. La pêche de 1995 a largement été alimentée par les classes de 1991 et 1992 qui constituaient 75 % environ du poids des débarquements. Les relevés indiquent un déclin de l'abondance des adultes depuis 1990 environ, à un niveau comptant parmi les plus faibles jamais notés, mais une tendance à la hausse est observée depuis 1993. Les indices obtenus pour la classe de 1992 portent à croire que cette classe est la plus importante à avoir été produite depuis celles de 1983, 1985 et 1987.

La cadre adaptatif a été utilisé pour l'étalonnage de l'analyse séquentielle de population à partir des tendances des relevés recherche. La biomasse des âges 3 et plus s'est accrue pour atteindre 23 000 t environ au début de 1996, après être tombée à moins de 10 000 t, soit presque le minimum historique. L'effectif de la classe de 1992, estimé à 17 millions environ, se compare à celui des classes de 1983, 1985 et 1987. La mortalité par pêche des âges 4 et plus a chuté à 0,16 en 1995; elle était de 0,6 en 1992 et 1993, soit la valeur la plus élevée notée depuis 1971.

Un rendement prévu de 6 800 t environ en 1996 correspondrait au taux de mortalité par pêche $F_{0.1}$ de 0,28 et donnerait lieu à une augmentation marginale de la biomasse des âges 3 et plus de 1 000 t environ. Près de la moitié du rendement prévu en 1996 et de la biomasse de 1997 est cependant attribuée à la classe de 1992. Une analyse des risques a montré que des prises de 5 000 t en 1996 permettraient de ne pas dépasser le taux de mortalité par pêche de niveau $F_{0.1}$ et d'accroître la probabilité que la biomasse augmente entre 1996 et 1997.

## DESCRIPTION OF THE FISHERY

The haddock on Georges Bank have supported a commercial fishery since the early 1920's (Clark et al. 1982). Record high landings were reported in the 1960s, reaching about 60,000t for eastern Georges Bank, unit areas 5Zjm (Fig. 1). From 1969 to 1992, landings ranged between 3,800t and 25,000t (Table 1, Fig. 2) and declined since 1992 to just over 2,000t. It was determined that substantial discarding of small haddock from the 1972, 1975 and 1978 year-classes occurred and catches were augmented to account for this (Overholtz et al. 1983). During 1988, almost 2,000t of haddock reported from unit areas 5Zjm in the Canadian fishery were suspected of originating from Division 4X. Landings for the year were adjusted accordingly.

A Total Allowable Catch was introduced in 1970 by the International Commission for the Northwest Atlantic Fisheries. Seasonal closures of haddock spawning areas were also instituted in that year as an adjunct and have been retained by Canada and the USA (Halliday 1988). Since 1977, with the extension of jurisdiction by coastal states, only Canada and the USA have conducted haddock fisheries on Georges Bank. Following the establishment of a maritime boundary in 1984 by the International Court of Justice, the Canadian and USA fisheries have been restricted to their respective jurisdictions.

Under increasingly restrictive management, total Canadian landings decreased from almost 4,000t in 1993 to about 2,000t in 1995. The quota of 2,500t for 1995 was not reached due to closure of the fisheries for most sectors when the cod quota was reached. Prior to 1994, allocations to fishery sectors in recent years have either been exceeded or have not been restrictive.

| Fishery Sector | 1992 | | 1993 | | 1994 | | 1995 | |
|---|---|---|---|---|---|---|---|---|
| | Quota | Catch | Quota | Catch | Quota | Catch | Quota | Catch |
| Fixed gear <65' | 1185 | 1377 | 1508 | 1216 | 791 | 784 | 592 | 357 |
| Mobile gear <65' | 2535 | 1704 | 2212 | 1646 | 1439 | 1206 | 1268 | 1175 |
| Fixed gear 65'-100' | 50 | 5 | 50 | 8 | 30 | 8 | 25 | 0 |
| Mobile gear 65'-100' | 50 | 55 | 32 | 32 | 30 | 33 | 25 | 27 |
| Vessels >100' | 1180 | 853 | 1198 | 826 | 710 | 290 | 590 | 444 |
| Totals | 5000 | 3994 | 5000 | 3728 | 3000 | 2411 | 2500 | 2003 |

Catches are from quota reports and may not correspond exactly with statistics.

Bottom otter trawl and longline have been the predominant gears in the Canadian fishery and landings by both have declined since 1992 (Table 2). The number of vessels participating in the fishery and the number of trips they made have also been decreasing since 1992. For 1995, vessels on individual quotas were not eligible to depart for a trip on Georges Bank with less than 2t of cod and 8t of haddock quota remaining. Fixed gear vessels were again required to choose between and designate either Georges Bank or Division 4X for their fishery during June to September. They could not fish both stock areas during 1995. Additionally, only vessels with a history since 1990 of 25t or more for 3 years of cod, haddock, pollock, hake or cusk combined could participate in the Georges Bank fishery. A small fish protocol (fisheries would be closed if

an unacceptably high proportion of the catch was comprised of small fish) with increased at-sea monitoring was also implemented during 1994 to protect incoming recruitment and continued in 1995. The traditional spawning closure during March 1 to May 31 has been extended to include January and February since 1994. Landings in recent years have generally peaked during June or July (Table 3) though substantial landings have also occurred in the past during the early months of the year. Though some discarding and mis-reporting may have occurred, the quality of information was reported to be much improved since 1992, after the introduction of dockside monitoring.

The USA fishery is almost exclusively an otter trawl fishery (Table 4). In recent years catches have generally been concentrated during the first half of the year, peaking in June (Table 5). During 1994 the USA extended the February to May spawning season closure into June and expanded the restricted area. For 1995, the expanded restricted area was retained and the closure was imposed year round. The 500 lb. haddock trip limit which was also introduced in 1994 continued in 1995. Mandatory log books were introduced in 1994, replacing the existing interview system for obtaining catch and effort information. Statistics for the 1994 and 1995 fisheries were not available but it is estimated that about 150t and 100t of haddock were landed in those years respectively (pers. comm. R.W. Brown, NMFS Woods Hole).

## CATCH AND WEIGHT AT AGE

The catch and weight at age for the commercial fishery from 1969 to 1994 were taken from Gavaris and Van Eeckhaute (1995). The catch for 1994 was adjusted for the reduced USA estimated landings. Catch and weight at age for 1995 were calculated by applying age length keys to length frequencies using the methods described by Gavaris and Gavaris (1983). Growth patterns of haddock do not appear to differ between the two unit areas 5Zj and 5Zm or between catches by gears participating in the fishery. Accordingly, age length samples were pooled to construct keys by quarter for each country where information was available. Length compositions of catches can vary between gears, therefore, length frequency samples were pooled within gears and applied to the respective landings before being aggregated to the level of age length keys. When landings occurred in a month-gear category for which samples were not available, suitable adjacent samples were used. Examination of comparative interpretation of ages from otolith samples by the 3 age readers involved did not reveal any problematic inconsistencies (see Appendix A).

The Canadian otter trawl fishery has undergone considerable evolution in recent years with a greater prevalence of square mesh in the codend. During 1995, all otter trawlers used square mesh but the nature of the fishery differed between vessels of tonnage class 3 and less and those of tonnage class 4 and greater. The 1995 Canadian commercial fishery was sampled sufficiently to permit computation of length and age composition for these separately as well as for longline and gillnet catches (Appendix B). The length frequency samples for 1995 were augmented with samples collected by at sea observers as in 1994 since examinations revealed that port and sea samples were comparable. The observer samples were obtained on a set by set basis and these were pooled to the trip level to make them compatible with port samples before

being combined with them. The calculations were done using the length-weight relationship which was derived from commercial fishery samples (Waiwood and Neilson 1985) ;

$$\text{round weight (kg)} = 0.0000158 \text{ length (cm)}^{2.91612}$$

During 1995, the otter trawl and longline catches peaked between 50 and 54 cm while the gillnet catches peaked at about 65 cm (Fig. 3) similar to what occurred in 1994.

Processing of USA sample information is linked to the landings database. As noted earlier, the mandatory logbook system introduced in 1994 for USA landings data has resulted in delays. Consequently, samples from the 1994 and 1995 USA fishery were not available. In the absence of samples for the USA fishery, the Canadian age composition for the June otter trawl fishery was applied to the estimated landings as most USA landings in recent years have occurred in the first half of the year. The USA catch at age for 1994 was adjusted to reflect the reduced landings estimate.

The fishery in 1995 was largely supported by the 1991 (average length of 56 cm) and 1992 (average length of 51 cm) year-classes which comprised about 75% of the landed weight. The 1987 (average length of 65 cm) year-class continued to contribute, accounting for about 8% of the landed weight (Fig. 4, Tables 6 - 11). Few age 2 haddock were caught compared to the average proportion caught during 1969-94, and this may be due in part to the use of square mesh by the otter trawl fleets and to monitoring associated with the small fish protocol. There were no marked, persistent, long term trends in weight at age however the year-classes after 1988 appear larger at age during 1991 to 1994. Fishery weights for most of these year-classes decreased in 1995. Weights at age obtained during the Canadian survey were examined to ascertain whether the increase in fishery weights at age observed for cohorts starting at age 2 with the 1989 year-class were reflecting an increase in growth. The average weights at age from the Canadian spring survey for 1986 to 1996 were determined (Fig. 5). The 1989 and 1990 year-class weights were generally higher than adjacent weights though not out of range when compared with the whole series. Cohorts after the 1990 show weights similar to earlier year-classes. The increased weights for the 1989 and 1990 year-classes in addition to fishery related factors are most likely causing the observed increase in weight at age. Contributing factors probably include changes to larger mesh size, the switch from diamond to square mesh for the otter trawlers, the small fish protocol in 1994 and changes in the seasonal pattern of fishing due to, for example, the introduction of ITQ's in 1992.

## ABUNDANCE INDICES

*Commercial Catch Rate*

The catch and effort data from tonnage classes 2 and 3 otter trawlers and longliners for 1993 to 1995 were summarized (Fig. 6). Only those vessels which fished during 1994 and reported more than 1t of landings for the year were selected for inclusion in these comparisons. Further, only trips or sub-trips where gadoid (cod, haddock and pollock) catch was 90% or more

of the total catch were included to avoid counting yellowtail or hake/cusk directed effort. For otter trawlers, the catch rate was computed as the catch per hour aggregated by month and tonnage class, while for longliners, the aggregate catch per trip was used since days fished were not available for 1994. The trends suggest that both otter trawl and longline catch rates increased progressively from 1993 to 1995. As in the past, catch rates from the commercial fishery were considered only for qualitative corroboration of results due to concern regarding comparability over years when fishing practices were changing.

*Industry/Science Surveys*

A survey of the Georges Bank area was completed by five longliners in July of 1995. The area was partitioned into equal sized boxes and one set was selected in each. Gear was standardized between vessels (number of hooks, hook size, bait, etc.) to minimize between vessel variance and boxes were assigned to vessels to achieve a mix of high and low expected catch rates. Twenty-two sets were completed and catches were sampled to determine length frequency and weight caught for cod and haddock. Catch rates and size composition were similar to those observed in the commercial fishery. This is the first year of this survey and as additional years of observation are completed, analyses will be conducted on the trends in abundance.

*Research Surveys*

Annual depth stratified random surveys have been conducted by the USA in the spring since 1968 and in the fall since 1963 (Fig. 7) and by Canada in the spring since 1986 (Fig. 8). Conversion factors to account for vessel and door changes (Tables 12 and 13) were applied to the USA surveys as suggested by O'Brien and Brown (1996). These conversion factors were slightly different than those used in previous assessments. Results for the 1995 Canadian survey were revised to correct for errors in strata designation of one set. The difference in results, due to these modifications, from those reported by Gavaris and Van Eeckhaute (1995) were minor. Fall survey results were compared to the beginning of year indices from the Canadian and USA spring surveys for the respective cohorts.

The distribution of haddock for 3 age groupings as observed from the three surveys are shown in Figs. 9, 10 and 11. The catches from the most recent surveys, 1995 for the USA and 1996 for Canada, are compared to the 1990 to 1994 long term averages (1990 to 1995 for the Canadian survey). In the fall, age 0 haddock are distributed throughout the 5Zjm survey area, but by spring, at age 1, they are more concentrated on the Canadian side although aggregations occur along the south-west flank in USA territory. In the fall, age 1 haddock are found along the edges of the bank in Canadian territory and have moved westward at age 2 the following spring. Spring concentrations are highest on the Canadian side with aggregations along the southern flank similar to age 1. In fall, the older ages are found along the edge of the bank, similar to the age 1 haddock, and they spread westward in spring, like the age 1 and 2 haddock. The older age groups appear to move somewhat further westward into USA territory. No change in distribution was noted for the most recent survey in each series when compared to the long term average.

Abundance estimates for ages 1 to 4 from the 1995 fall USA survey increased substantially from the previous year's estimates of the same cohorts (Table 16). This may have resulted from the distribution of sampling locations as there were proportionately more sets in areas where abundance is higher, i.e. near the north and east edge of the bank.

Abundance trends for ages 3-8 increased during the late 1970s after having declined to their lowest in the early 1970s. Following a rapid decline in the early 1980s, abundance remained stable at relatively low levels through the mid to late 1980s before declining again in the early 1990s, approaching the lowest levels observed. An increasing trend has been observed since 1992-93 (Tables 14-16, Fig. 13). Note that the fall surveys are compared to the beginning of the subsequent year. Survey results for ages 1 and 2 identified the strong 1975 and 1978 year-classes and the moderate 1983, 1985 and 1987 year-classes. Recruitment since then has been low but the 1992 year-class appears comparable to those of 1983, 1985 and 1987 while the 1993 year-class does not appear as abundant. Preliminary indications suggest that the 1994 and 1995 year-classes are about a third to a half the abundance of the 1992 year-class.

## ESTIMATION OF STOCK PARAMETERS

The adaptive framework, ADAPT, (Gavaris 1988) was used to calibrate the sequential population analysis with the research survey results using the following data :

$C_{a,y}$ = catch
for ages $a$ = 1 to 8 and for years $y$ = 1969 to 1995 and

$I_{s,a,y}$ = abundance index
for $s$ = Canadian spring survey, ages $a$ = 1 to 8, years $y$ = 1986 to 1996;
USA spring survey, ages $a$ = 1 to 8, years $y$ = 1969 to 1995;
and USA fall survey, ages $a$ = 0 to 5, $y$ = 1968 to 1995.

The spring survey results were compared to beginning of year population abundance in the same year while the fall survey results were compared to beginning of year population abundance in the following year for the respective cohort. The frequent occurrence of zero catches and the large variation in the relationship between population abundance and USA fall survey indices at ages 6 and 7 led to the exclusion of these ages. All other available data since 1968 were used except when the indices were 0 (logarithm not defined). During years when discarding was high, survey information was used along with interviews to obtain estimates of the USA catch. This lack of complete independence between catch and survey data does not influence population estimates but may deflate variance estimates marginally. The model formulation employed assumed that the error in the catch at age was negligible. The error in the survey abundance indices was assumed to be independent and identically distributed after taking natural logarithms of the values. Natural mortality, $M$, was assumed constant and equal to 0.2 and fishing mortality, $F$, for age 8 was assumed equal to the arithmetic average for ages 4 to 7.

Following Gavaris (1993), a model formulation using as parameters the ln population abundance at the beginning of the year following the terminal year for which catch at age is available was considered. The following model parameters were defined:

$\theta_{a,1996}$ = ln population abundance
for $a$ = 1 to 8 at the beginning of the year 1996,

$\kappa_{s,a}$ = ln calibration constants
for each survey source, denoted by $s$, and the relevant ages.

ADAPT was used to solve for the parameters by minimizing the sum of squared differences between the ln observed abundance indices and the ln population abundance adjusted for catchability. The objective function for minimization was defined as

$$\Psi(\theta,\kappa) = \sum_{s,a,y} \left(\ln I_{s,a,y} - \kappa_{s,a} + \ln N_{a,y}(\theta)\right)^2$$

For convenience, the beginning of year population abundance $N_{a,y}(\theta)$ is abbreviated by $N_{a,y}$. For year y = 1996, the population abundance was obtained directly from the parameter estimates, $N_{a,1996} = e^{\theta_{a,1996}}$. For all other years, the population abundance was computed using the virtual population analysis algorithm which incorporates the exponential decay model

$$N_{a,y} = N_{a+1,y+1} e^{F_{a,y}+M}$$

where the natural mortality $M$ is assumed and the fishing mortality $F_{a,y}$, for ages $a$ = 1 to 7, is obtained by solving the catch equation using a Newton-Raphson algorithm

$$N_{a,y} = \frac{C_{a,y}\left(F_{a,y}+M\right)}{F_{a,y}\left(1-e^{-\left(F_{a,y}+M\right)}\right)}$$

The fishing mortality rate for age 8 was assumed equal to the average for ages 4 to 7.

$$F_{8,y} = \sum_{a=4}^{7} F_{a,y} \Big/ 4$$

The magnitude of the residuals is large, particularly for younger ages in the USA fall surveys. The text table below shows the average of squared residuals for each series.

| Survey | Age | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Can. Spring | .58 | .93 | .29 | .21 | .52 | .62 | .66 | .19 |
| USA Spring | 1.12 | .86 | .60 | .31 | .50 | .88 | 1.34 | .79 |
| USA Fall | 1.37 | 1.79 | 1.23 | .74 | .61 | .76 | | |

Though several large residuals occur (Fig. 12), the respective observations do not appear to be influential and should not unduly distort parameter estimates. For example, the Canadian survey

observation for age 1 in 1987 appears low but the calibration line appears to fit the other observations. The residuals for the most recent year of observation are generally small except for the USA fall survey at age 3 where it is amongst one of the larger residuals. The age 3 USA fall survey abundance accounted for about half of the total abundance, an unexpected result as the 1993 year-class is not estimated to be that strong in any other survey. The variance and bias of population abundance estimates and corresponding projected yield were derived using an analytical approximation (Gavaris 1993). The population abundance estimates show a large relative error and substantial bias at ages 1 and 2 reflecting the variability in the abundance indices (Table 17). However, the survey indices, scaled by the calibration constants and converted to biomass, correspond well with the trends estimated by the sequential population analysis (Fig. 13).

*Index error assumptions*

Myers and Cadigan (1995) reported that correlated errors among ages within years of a survey can be sufficiently large to produce model mis-specification biases in estimates of population parameters from standard assessment methods. Their simulation however, showed that maximum likelihood estimators from models which ignored correlation performed similar to those from models which incorporated correlation when the correlated errors were small, e.g. $\rho = 0.15$ . An estimate of the correlation between ages within years was computed using the standard sample estimator for the coefficient of linear correlation where the pairs of observations were the residuals from each abundance index source: $(e_{i,y}, e_{j,y})$ for all ages $i \neq j$ and all years $y$. For the three survey sources used in this assessment, the correlation was found to be small; Canadian spring survey $\hat{\rho} = 0.01$, USA spring survey $\hat{\rho} = 0.17$ and USA fall survey $\hat{\rho} = 0.18$. Accordingly, no further corrective measures were taken to account for bias from this type of model mis-specification for this stock.

*Catch at age error assumptions*

The calibration model employed assumes that the catch at age is known without error. Some calibration models allow for random error in the observed catch at age but to keep the number of estimated parameters at a practicable small number, they impose a constant exploitation pattern by age over years. We consider that the random error in the catch at age is indeed small relative to the error in the indices but that systematic error in the catch at age which may be introduced due to biased reporting of landings could be significant. Systematic errors are not adequately handled by models which assume random error. To investigate the impact of such systematic error, we employed two alternative models which did not use the suspect data and compared the results with those from the previous traditional assessment (Gavaris and Van Eeckhaute 1995). With both these models, only relative year-class abundance and fishing mortality rates can be estimated. Estimation of absolute abundance requires scaling of the sequential population analysis with known catch at age. For convenience in comparisons, the relative year-class abundances were scaled to the 1994 age 1 abundance from the traditional calibration. The approach is similar to that described by Gavaris (1991) for exploring how ADAPT could be used with alternative model assumptions and information sources to

investigate the robustness of parameter estimates from traditional calibration models. The following text table summarizes the traditional and variant model formulations. Details of the computations for the alternative models are provided in Appendix C.

| | Traditional | Proportion Caught at Age and Abundance Indices | Abundance Indices |
|---|---|---|---|
| Input Data | $C_{a,y}$ = catch<br>ages $a$ = 1 to 8<br>years y = 1969 to 1995 | $P_{a,y}$ = proportion caught<br>ages a = 1 to 8<br>years y = 1969 to 1994 | N/A |
| | $I_{s,a,y}$ = abundance index<br>$s$ = Canadian spring survey, ages $a$ = 1 to 8, years y = 1986 to 1996;<br>USA spring survey, ages $a$ = 1 to 8, years y = 1969 to 1995;<br>USA fall survey, ages $a$ = 0 to 5, y = 1968 to 1995 | | |
| Parameters | $\theta_{a,1996}$ = ln population abundance<br>ages $a$ = 1 to 8 at the beginning of the year 1996 | $\theta_{a,1996}$ = ln population abundance<br>ages $a$ = 2 to 8 at the beginning of the year 1996 | |
| | $\kappa_{s,a}$ = ln calibration constants | $\kappa_{s,a}$ = ln calibration constants<br>common calibration constant for ages 3 to 8 | |
| | N/A | $\varphi_{5,y}$ = ln fishing mortality<br>years y = 1969 to 1994 | $\varphi_{a,y}$ = fishing mortality<br>ages a=2,3,4<br>years y = 1969 to 1994 |
| Objective function | $\underset{s,a,y}{\Psi}(\theta,\kappa) = \sum_{s,a,y}\left(\ln I_{s,a,y} - \kappa_{s,a} + \ln N_{a,y}(\theta)\right)^2$ | | |
| Assumptions | constant natural mortality; M = 0.2 | | |
| | $F_{8y} = \sum_{a=4}^{7} F_{ay} \Big/ 4$ | N/A | $N_{8,y} = \sum_{a=4}^{7} \frac{N_{a,y}P_{8,y}}{P_{a,y}} \Big/ 4$ |

The first model option represents the situation where landings are not reported accurately due to non-reporting or mis-reporting by area or species. Samples obtained from the fishery though, would be representative of the size and age composition of the catch. This model estimates relative year-class abundance and fishing mortality using abundance indices and proportion caught at age in the commercial fishery based on sampling information but does not employ landings data. The results from this model agree fairly well with those from the traditional calibration model (Fig. 14). The relative magnitude of most year-classes showed good correspondence except for the 1971, 1972 and 1975 year-classes. Fishing mortality estimates were erratic, displaying more extreme values, but their average magnitude approximated estimates from the traditional model. The wide fluctuations in fishing mortality are a reflection of the variability in the abundance indices. Fishing mortality estimates from traditional calibration models are tempered by the information contained in the catch at age.

The second model option represents the case where activities at sea such as high-grading, discarding or dumping distort the estimates of proportion caught at age which are obtained by

sampling landings. This model considers that even the sampling information is unreliable and estimates relative year-class abundance and fishing mortality using abundance indices, employing proportion caught at age only for fully recruited ages to calculate oldest age abundance. The results from this model indicate that estimates of year-class abundance for larger year-classes prior to the early 1980s were generally greater than traditional estimates (Fig. 15). This could have been caused by greater discarding at sea of small haddock during those years, resulting in unrepresentative sampling. Estimated fishing mortality at age 2 was very erratic and was also considerably higher than the traditional estimates on average. This reflects the confounding of survey catchability and survival for ages which are not fully recruited to the fishery. Essentially, it is not possible to estimate mortality on the ascending limb of a catch curve. Estimated fishing mortality for age 3 and for ages 4+ are also fairly erratic but their average level generally corresponds to the estimates from the traditional model. This reflects the variability of abundance index estimates and confirms that annual estimates of total mortality obtained from indices alone will be too imprecise for practical purposes but it may be possible to extract average trends. It appears then that the general level of exploitation estimated from the traditional model may not be unduly impacted by the degree of high-grading, discarding or dumping which might have occurred, but the estimates of relative year-class abundance may be distorted.

The comparison of results from these two model variants and the traditional model suggest that the information on year-class abundance estimates contained in the abundance index observations may not be consistent with the sequential population information contained in the catch at age. To investigate further whether the estimates of abundance for contemporary year-classes may be biased due to systematic errors in the catch at age, the traditional assessment model was applied to data since 1981. This was done because it is known that there were substantial discards at ages 1 and 2 of the 1975 and 1978 year-classes (Overholtz et. al. 1983). The comparison in the following text table suggests that use of all years from 1969-96 results in somewhat lower contemporary population abundance estimates. Considering the uncertainty in the estimates, these differences would not be significant but the pattern warrants further investigation.

| Years | Age | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1969-96 | 5738 | 4420 | 5965 | 8645 | 2079 | 339 | 193 | 13 | 363 |
| 1981-96 | 6832 | 5234 | 6742 | 9505 | 2357 | 392 | 233 | 21 | 434 |

*Age structure assumptions*

Calibration of sequential population analysis relies on age structured data. Production models offer an alternative for estimation of stock status. They are typically less demanding of information, not requiring age structure, but they incorporate more assumptions about population dynamics than calibrated sequential population analysis models. ASPIC, a production model which accepts multiple indices of abundance (Prager 1994, 1995), was used to estimate population parameters and reconstruct the predicted stock history. The yield for ages 3 and older

was used with the survey biomass for ages 3 and older, from the three survey sources, in fitting the model. These data did not fit the model well, particularly near periods of high recruitment when biomass was low. Production models implicitly incorporate a stock-production relationship and do not perform well for relatively short lived species with highly variable recruitment which is not correlated to stock biomass (Prager 1994). The results from these attempts were not considered reliable and are not reproduced here.

## ASSESSMENT RESULTS

The examination of parameter estimates and diagnostics and the evaluation of assumptions regarding error correlation, catch misreporting and age structure, indicate that the results from the traditional SPA calibration model using all data from 1969 should provide a reasonable basis for interpretation of stock status. For each cohort, therefore, the terminal population abundance estimates from ADAPT were adjusted for bias and used to construct the history of stock status (Tables 18,19). Gavaris and Van Eeckhaute (1994) considered that this approach for bias adjustment, in the absence of an unbiased point estimator with optimal statistical properties, was preferable to using the biased point estimates. The weights at age from the Canadian spring survey (Table 20) were used to calculate beginning of year population biomass for 1986-96 (Table 21). A weight of 2.6 kg was used for age 7 in 1995. For 1969-85, the 1986-96 average weight at each age was used. A weight of 3.4 kg was used for age 9 in all years.

By the mid 1970s, following heavy exploitation by foreign distant water fleets, biomass had decreased to its lowest recorded level, but subsequently increased as the strong 1975 and 1978 year-classes recruited (Figs. 16, 17). The stock biomass again declined rapidly in the early 1980s as subsequent recruitment was poor and these two year-classes were fished intensely at a young age (Fig. 18). The biomass fluctuated around 18,000t during the late 1980s, supported by the 1983, 1985 and 1987 year-classes, which were estimated to be the most abundant since the strong 1975 and 1978 year-classes, before declining to about 13,000t in 1993. The biomass has since steadily increased to about 26,000t in 1996. The recent increase, due principally to the 1992 year-class, but also supported by the 1991 and 1993 year-classes, was enhanced by increased weight at age of haddock from the 1989 and 1990 year-classes as well as increased survivorship of young haddock from reduced capture of small fish in the commercial fisheries. The biomass trend for ages 3 and older is similar to total biomass but at a lower magnitude. The strength of the 1992 year-class was estimated to be about 17 million, comparable to the 1983, 1985 and 1987 year-classes while those between 1987 and 1991 were weak (Table 18 and Fig. 17). The 1991 and 1993 year-classes were estimated at about a third to a half of the magnitude of the 1992 year-class while the 1994 year-class was estimated to be weaker at about 5 million. Early indications for the 1995 year-class suggest that it is also weak at about 5 million. The fishing mortality rate for ages 4 and older has generally exceeded $F_{0.1} = 0.25$ and increased markedly between 1989 and 1992 to about 0.6, amongst the highest observed (Table 19 and Fig 18). The previous occasion when the fishing mortality exceeded 0.5 was during the early 1970s when abundance was at its lowest. The exploitation rate declined moderately in 1993, but then more substantially in 1994 and 1995 to a level below the $F_{0.1}$ target.

Results from assessments for several other stocks have revealed a discrepancy between past estimates of stock status and current estimates using additional data. Generally, the current estimates are more optimistic but as additional data becomes available, the current view of the past is more pessimistic. This characteristic has been referred to as a retrospective pattern. Examination of year-class estimates at age 1 from assessments done using a comparable formulation with years 1990 through 1995 considered the terminal year for the assessment show remarkable consistency (Fig. 19). It was concluded that this stock assessment does not suffer from a retrospective pattern.

The Georges Bank ecosystem is complex with numerous species interactions. Further, species adapt to fluctuations in abundance of both their prey and predators. These interactions were modeled by a constant natural mortality and there were no indications that this assumption was severely violated. Currently available information does not permit more complex models to be employed.

Environmental conditions on Georges Bank have varied but have not displayed extreme deviations in recent years (Page et. al. 1996). Though environmental conditions are thought to influence fisheries processes, convincing relationships with quantities such as recruitment, survival rates and fish catchability have not been established.

## Yield Per Recruit

Clark et al. (1982) reported results from a yield per recruit analysis showing $F_{0.1}$ ranging from 0.21 to 0.26 with the age of full recruitment ranging from 2-3. Gavaris (1987) investigated the effect of varying minimum fish size on yield per recruit and effort under an $F_{0.1}$ strategy. Recent assessments have used an $F_{0.1}$ of 0.25 (Gavaris and Van Eeckhaute 1995) and 0.24 (O'Brien and Brown 1996).

Recently, a significant gear change occurred in Canada during 1993 and 1994 when diamond mesh otter trawl gear was replaced with square mesh. By 1995 all Canadian otter trawlers were required to use square mesh. The change in gear selectivity on smaller fish can potentially affect the partial recruitment to the fishery and the fishery weights at age. A yield per recruit analysis was therefore undertaken to determine the impact on $F_{0.1}$.

Yield per recruit was determined using the Thompson and Bell method (Rivard 1982). Average weights at age were determined from the annual average weights at age from the 5Zjm commercial fishery (Fig. 20). For ages 1 to 3, 1993-95 weight data was used as these years reflect the change in gear selectivity for the younger fish. For the fully recruited ages, 4-16, 1985-95 data were used as these years were viewed as representative of the recent seasonal fishing pattern. Three outliers, two in 1994 at age 13 and 14 and one at age 12 in 1980 were omitted as only 2, 1 and 1 fish, respectively, were aged. Partial recruitment to the fishery has changed in recent years and values used follows Gavaris and Van Eeckhaute (1995). The oldest age was based on the oldest observed age from Canadian surveys since 1986 and Canadian commercial fishery samples. The input data are summarized below:

| Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wgt.(kg) | 0.62 | 1.111 | 1.63 | 1.903 | 2.235 | 2.569 | 2.878 | 3.26 | 3.395 | 3.549 | 3.968 | 4.235 | 4.273 | 4.288 | 4.505 | 4.798 |
| PR | 0 | .05 | .5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

The resulting yield per recruit and yield per unit effort are shown in Fig. 21. $F_{0.1}$ increased to 0.28 from 0.25, the value used in previous assessments of this stock.

## PROGNOSIS

Yield projections were done using the 1995 beginning of year population numbers as estimated from ADAPT, the average fishery catch weight at age for 1993-95 for the yield and the average Canadian spring survey weight at age for 1994-96 for the beginning of year biomass. Following Gavaris and Van Eeckhaute (1994), the partial recruitment to the fishery for ages 1, 2 and 3 was 0, 0.05 and 0.5 respectively. The abundance of year-classes after 1995 was assumed to be 10 million, but this assumption does not affect short term forecasts. As with the population abundance estimates, the adjustment for bias of the projected yield was considered more appropriate than using the biased point estimate. The projected yield at $F_{0.1} = 0.28$ in 1996 would be about 6,800t with the 1992 year-class accounting for more than half of the landed weight (Table 22, Fig. 22). The biomass for ages 3 and older is projected to increase marginally from 23,000t to over 24,000t at the beginning of 1997 with the 1992 year-class accounting for almost half of that biomass.

## MANAGEMENT CONSIDERATIONS

With the current state of the stock, the 1992 year-class makes a relatively large contribution to the projected yield. As the 1992 year-class gets fished down, the biomass will decline unless there is good recruitment. Uncertainty regarding the abundance of any single year-class gets translated to the projected yield which, in this case, had a relative error of roughly 25%. A yield of about 5,000t should ensure that $F_{0.1}$ is not exceeded and increases the chances that the biomass for ages 3 and older will increase between 1996 and 1997 (Fig. 23). The calculations of uncertainty are based on approximations and do not include variations in weight at age or partial recruitment and other factors but should provide useful rough guidelines. Increasing the number of age groups contributing to the yield should lead to greater precision in the advice. Increased abundance over a broader age span would also moderate fluctuations in biomass caused by recruitment variability and result in more stable yield between years. A larger spawning biomass could enhance recruitment by capitalizing on the opportunities for greater egg and larval survival when environmental conditions are favorable.

The projected increase in haddock abundance is due primarily to recruitment of one year-class, the moderately strong 1992 year-class, but is also bolstered by the adjacent 1991 and 1993 year-classes. Continuing conservation efforts such as low exploitation and fishing practices

which permit recruits to realize their growth and reproductive potential are needed to sustain the rebuilding of the population biomass and to expand the age structure.

*Carry-over allocations*

The Groundfish Management Plan is issued annually and designates allocations to fishermen for the calendar year. The allocations must be caught in the calendar year in which they are granted. For a variety of reasons other than low abundance of the target species, fishermen may choose not to catch their entire allocation (Gavaris and d'Entremont in press). Fishermen with some of their allocation remaining at the end of the year receive no credit though leaving fish in the water may have actually been beneficial or at worst, benign. Consequently allocations are often viewed as a limit which must be reached by the end of the year. This may lead to dangerous situations where fishermen sail under unfavorable conditions towards the end of the year in order to catch their remaining allocation rather than lose it. Further, in complex multi-species fisheries, fishermen are challenged to exhaust all their allocations simultaneously. This situation may create an undesirable incentive to dump species with lower quotas. Finally, in multi-species fisheries, a fisherman may choose, for operational reasons, not to pursue a particular fishery in a given year. These fishermen are faced with foregoing any benefits, temporarily selling their allocation or permanently selling their allocation.

The complications created by annual allocations may be alleviated by permitting fishermen to carry-over uncaught allocation into the subsequent fishing season (Gavaris and d'Entremont in press). This is accomplished by taking the uncaught quantity and projecting it forward into the subsequent fishing season to determine what amount it would represent after accounting for losses due to natural deaths and gains due to fish growth. This amount would be the maximum carry-over. Using the 1995 haddock fishery in 5Zjm as an example, where about 436t were left uncaught during 1995, the maximum carry-over into 1996 would be 445t. It was assumed that the age composition of the 436t of uncaught haddock was the same as that for the 2,064t which were caught (Table 23). The numbers were diminished by applying the assumed natural mortality rate of 0.2 for a period of one year (Table 23, Fig. 24). The carry-over biomass for 1996 was obtained by applying the weight at age to the carry-over numbers. Though there is a net loss in weight for older year-classes, fast growth at younger ages results in a net gain for tonnage carried over (Table 23, Fig. 25).

Allowing a carry-over may lead to greater depletion of the population biomass than would have occurred if the allocations had been caught in the year they were granted. To prevent this, the maximum carry-over is reduced to the permitted carry-over level. To determine the permitted carry-over in the haddock example, a projection is conducted starting with the 1995 estimated population abundance, assuming that the full 2,500t allocation was caught and forecasting for 1996 at the target fishing mortality rate, $F_{0.1} = 0.28$. This results in a beginning of year 1997 biomass for ages 2 and older (age 1 is assumed recruitment) of 26,659t and a yield in 1996 of 6,691t. The yield of 6,691t is the amount that would be allocated in 1996 according to traditional shares. If the maximum carry-over of 445t were allowed the total allocation in 1996 would amount to 7,136t. A projection starting with the 1996 estimated population abundance, assuming a catch of 7,136t in 1996, results in a 1997 beginning of year biomass of 26,601t, less than the

26,659t benchmark. A projection starting in 1996, assuming a catch of 7,091t in 1996, which corresponds to a 400t carry-over, results in a 1997 beginning of year biomass approximating the 26,659t benchmark. Therefore, the permitted carry-over for 1996 would be about 400t and could be allocated among those fishery sectors which had not caught their allocations in proportion to the amount they had left.

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Appendix A. Aging comparisons.

There are 3 readers for 5Z haddock, N. Munroe for the USA and M. Strong and L. Van Eeckhaute for Canada. A summary of inter-reader tests between the 3 readers and intra-reader tests for the Canadian readers is presented in Table A1. Percent agreement is calculated as: the number of otoliths aged the same ÷ by the no. aged by both readers × 100.

Otoliths for the USA/Canada exchange were selected from the USA spring and fall 1993 and 1994 and the spring 1995 surveys. N. Munroe's ages for the 1995 spring survey were not available for this report. Otoliths for Canadian tests were selected from the 1994 and 1995 commercial fishery samples and from the 1995 spring survey. Otolith selections for Canadian tests covered the entire length range and incorporated seasonal aspects.

*Intra-reader tests*

Percent agreements for L. Van Eeckhaute and M. Strong were 88% and 81%, respectively, with no bias detected.

*Inter-reader tests*

Although there was some bias between the Canadian readers versus the USA reader, agreement was considered acceptable and the bias was not expected to impact results substantially. To address the bias problem, images of the problem otoliths with L.Van Eeckhaute's interpretations were sent to NEFSC so that age interpretations could be compared. Results have not yet been received.

Canadian inter-reader agreement for the Can/USA exchange was acceptable at 79% with no bias detected. Agreement for the 1994 commercial fishery samples and the Canadian spring survey was somewhat lower but still acceptable at 77%, however some bias was detected (see Table A1). To address the bias problem, interpretations were compared using annotated images. Several causes were identified (numbers following indicate frequency of problem):

- when reading the proximal axis, one reader assigned 2 hyaline zones to the 2nd annulus while the other reader counted each zone as an annulus (5)
- difference in interpretation of 1st and 2nd annulus on ventral axis (4)
- several otoliths were cut off center making interpretation more difficult (3)
- interpretation of hyaline zone as check or annulus (2)
- edge counted by one reader and not the other (2)

No bias was observed in the last test using otoliths from the 1995 commercial fisheries samples, which followed the above comparison of age interpretations, and agreement was satisfactory.

Questionable ages identified by inter-reader tests and comparison of age-length keys from the two Canadian readers were re-examined as well as 50 otoliths which were cut off center in the Canadian spring survey. Those without consensus were omitted from the database and ages revised where appropriate.

Table A1. Summary of inter- and intra-reader aging tests for 5Z haddock in 1995.

| Source | | Qty | Prod-uction Read By | Test Req-uirements | | Test Results | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Between Reader | | | Within Reader | |
| | | | | LVE | MS | NMxMS | NMxLVE | MSxLVE | MS | LVE |
| Can/USA | 9302 | 39 | NM | 39 | 39 | 72% (105) NM+ | 83% (105) NM+ | 79% (155) | | |
| | 9306 | 14 | NM | 14 | 14 | | | | | |
| | 9402 | 33 | NM | 33 | 33 | | | | | |
| | 9406 | 19 | NM | 19 | 19 | | | | | |
| | 9503 | 50 | NM | 50 | 50 | | | | | |
| CGS 1994 (Blind Test) | Q2 | 36 | LVE | 36 | 36 | | | 77% (68) | 77% (103) MS+ | | 88% (68) |
| | Q4 | 32 | LVE | 32 | 32 | | | | | |
| | Q3 | 35 | MS | 35 | 35 | | | 75% (35) | | 69% (35) | |
| N216 | 1-350 | 350 | MS | 30 | 30 | | | 71% (65) MS- | | 96% (30) | |
| | 351-700 | 350 | LVE | 35 | 35 | | | | | | 88%(35) |
| CGS 1995 | Q2 | 166 | LVE | | 108 | | | 83% (109) | | | |
| | | 0 | MS | | | | | | | | |
| | Q3 | 53 | LVE | | | | | | | | |
| | | 231 | MS | 105 | | | | 85% (105) | | | |
| | Q4 | 108 | LVE | | | | | | | | |
| | | 113 | MS | | | | | | | | |

NM=N. Munroe
MS=M. Strong
LVE=L. Van Eeckhaute

Ageing bias is indicated by a '+' or '-' after unsuals, indicating overaging or underaging, with respect to the other ager.
CGS=Commercial Fishery Samples

Appendix B. Derivation of catch at age for the 1995 5Zjm haddock fishery.

| Country | Qtr. | Length Frequency Samples | | | | | | | | | Aged Samples | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Gear | Month | Observer | | Port | | Landings | Combinations | | No. of Samples | No. Aged |
| | | | | Samples | Measured | Samples | Measured | (kg) | | | | |
| Canada | 1 | Misc. | Jan | 1 | 117 | | | 1,284 | JanMisc | CanQ1 | 5 | 166 |
| | | | Feb | | | | | 744 | | | | |
| | | | Mar | 2 | 123 | | | 1,103 | MarMisc | | | |
| | 2 | OTIN | June | 2 | 1701 | 3 | 841 | 572,281 | Q2OTOF | CanQ2 | | |
| | | OTOF | June | | | 2 | 401 | 123,595 | Q2OTIN | | | |
| | | GN | June | | | 1 | 228 | 3,299 | Q2GN | | | |
| | | LL | June | 3 | 396 | | | 61,941 | Q2LL | | | |
| | | Misc | Apr | | | | | 674 | | | | |
| | | | May | | | | | 345 | | | | |
| | | | June | | | | | 1,123 | | | | |
| | 3 | OTIN | Jul | 2 | 1573 | | | 179,879 | JulOTIN | CanQ3 | 10 | 277 |
| | | | Aug | | | 8 | 1873 | 196,238 | AugOTIN | | | |
| | | | Sept | | | 2 | 455 | 171,276 | SepOTIN | | | |
| | | OTOF | Jul | Used Q2OTOF | | | | 16,518 | Q3OTOF | | | |
| | | | Sept | | | | | 29,801 | | | | |
| | | GN | Jul | Used Q2GN | | | | 3,992 | Q3GN | | | |
| | | | Sept | | | | | 14,231 | | | | |
| | | LL | Jul | 2 | 147 | | | 124,187 | Jul LL | Q3LL | | |
| | | | Aug | 5 | 2799 | | | 92,899 | AugLL | | | |
| | | | Sept | | | | | 65,308 | | | | |
| | | Misc | Jul | | | | | 1,235 | | | | |
| | | | Aug | | | | | 452 | | | | |
| | | | Sept | | | | | 8 | | | | |

| Country | Qtr | Length Frequency Samples | | | | | | | | | | Aged Samples | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Gear | Month | Observer | | Port | | Landings (kg) | Combinations | | | No. of Samples | No. Aged |
| | | | | Samples | Measured | Samples | Measured | | | | | | |
| Canada | 4 | OTIN | Oct | | | 1 | 200 | 90,559 | OctOTIN | Q4OTIN | CanQ4 | 8 | 209 |
| | | | Nov | 1 | 463 | 6 | 1370 | 138,200 | NovOTIN | | | | |
| | | | Dec | | | 1 | 230 | 70,345 | | | | | |
| | | OTOF | Oct | | | | | 76 | | Q4OTOF | | | |
| | | | Nov | 5 | 1611 | 2 | 469 | 36,893 | NovOTOF | | | | |
| | | | Dec | 1 | 35 | 1 | 215 | 21,259 | DecOTOF | | | | |
| | | LL | Oct | | | | | 18,539 | Q4LL | | | | |
| | | | Nov | | | 1 | 234 | 21,543 | | | | | |
| | | | Dec | | | | | 4,323 | | | | | |
| | Totals | | | 24 | 8,965 | 28 | 6,516 | 2,064,151 | | | CAN | 23 | 652 |
| USA | Total | Can. If samples from JunOTIN | | | | | | 100,000 | | | USA | | |
| Total landings for Canada and USA | | | | | | | | 2,164,151 | | | | | |

OT=Otter Trawl, GN=Gill Net, LL=Long Line, IN=Inshore (Tonnage Classes <=3), OF=Offshore (Tonnage Classes >=4), Q=Quarter

Appendix C. Alternative models which did not use catch at age.

*Proportion Caught at Age & Abundance Indices*

This model estimates relative year-class abundance and fishing mortality using abundance indices and proportion caught at age in the commercial fishery based on sampling information but does not employ landings data:

$P_{a,y}$ = proportion caught at age in year y
for ages a = 1 to 8 and for years y = 1969 to 1994 and

$I_{s,a,y}$ = abundance index
for s = Canadian spring survey, ages a = 1 to 8, years y = 1986 to 1995
USA spring survey, ages a = 1 to 8, years y = 1969 to 1994
and USA fall survey, ages = 0 to 5, y = 1968 to 1994

The following model parameters were defined:

$\theta_{a,1995}$ = ln population abundance
for a = 2 to 8 at the beginning of the year 1995,

$\varphi_{5,y}$ = ln fishing mortality
for age 5 and years y = 1969 to 1994 and

$\kappa_{s,a}$ = ln calibration constants
for each survey source, denoted by s, and the relevant ages.

Results from a preliminary trial indicated that ages 3 to 8 were fully recruited to the spring surveys. To minimize the number of parameters estimated, a constant calibration constant was used for ages 3 to 8 for each of the Canadian and USA spring surveys. The objective function for minimization was defined as

$$\Psi(\theta,\varphi,\kappa) = \sum_{s,a,y} \left(\ln I_{s,a,y} - \kappa_{s,a} + \ln N_{a,y}(\theta,\varphi)\right)^2$$

For convenience, the beginning of year population abundance $N_{a,y}(\theta,\varphi)$ is abbreviated by $N_{a,y}$. For year y = 1995, the population abundance was obtained directly from the parameter estimates, $N_{a,1995} = e^{\theta_{a,1995}}$. For all other years, the population abundance was computed using the virtual population analysis algorithm which incorporates the exponential decay model

$$N_{a,y} = N_{a+1,y+1} e^{F_{a,y}+M}$$

where the natural mortality $M$ is assumed and the fishing mortality $F_{a,y}$, $a \neq 5$, is obtained by solving the following equation using a Newton-Raphson algorithm

$$\frac{N_{a+1,y+1}F_{a,y}\left(e^{F_{a,y}+M}-1\right)}{P_{a,y}\left(F_{a,y}+M\right)}=\frac{N_{6,y+1}F_{5,y}\left(e^{F_{5,y}+M}-1\right)}{P_{5,y}\left(F_{5,y}+M\right)}$$

and $F_{5,y}=e^{\varphi_{5,y}}$.

During the iterative estimation process, some $\varphi_{5,y}$ values tended towards zero, therefore it was necessary to constrain estimation by applying a penalty function for $\varphi_{5,y}$ estimates less than 0.05.

*Abundance Indices*

This model estimates relative year-class abundance and fishing mortality using abundance indices, employing proportion caught at age only for fully recruited ages to calculate oldest age abundance:

$I_{s,a,y}$ = abundance index
for s = Canadian spring survey, ages a = 1 to 8, years y = 1986 to 1995
USA spring survey, ages a = 1 to 8, years y = 1969 to 1994
and USA fall survey, ages = 0 to 5, y = 1968 to 1994

The following model parameters were defined:

$\theta_{a,1995}$ = ln population abundance
for a = 2 to 8 at the beginning of the year 1995,

$\varphi_{a,y}$ = fishing mortality
for ages a=2,3,4 and years y = 1969 to 1994 and

$\kappa_{s,a}$ = ln calibration constants
for each survey source, denoted by s, and the relevant ages.

As was done with the first model, a constant calibration constant was used for ages 3 to 8 for each of the Canadian and USA spring surveys. The objective function for minimization was defined as

$$\underset{s,a,y}{\Psi}(\theta,\varphi,\kappa)=\sum_{s,a,y}\left(\ln I_{s,a,y}-\kappa_{s,a}+\ln N_{a,y}(\theta,\varphi)\right)^2$$

For convenience, the beginning of year population abundance $N_{a,y}(\theta,\varphi)$ is abbreviated by $N_{a,y}$. For year y = 1995, the population abundance was obtained directly from the parameter estimates, $N_{a,1995}=e^{\theta_{a,1995}}$. For all other years, the population abundance was computed using the virtual population analysis algorithm which incorporates the exponential decay model

$$N_{a,y} = N_{a+1,y+1} e^{F_{a,y}+M}$$

where the natural mortality $M$ is assumed and the fishing mortality $F_{a,y}$, for ages 2,3 and 4 was obtained from $F_{a,y} = \varphi_{a,y}$. The fishing mortality for age 1, was assumed to be zero for all years and the fishing mortality for ages 5 to 8 was assumed to be equal to the fishing mortality at age 4 in the same year. The population abundance at age 8 for years y = 1969 to 1994 was calculated using the proportion caught at age for ages 4 to 8

$$N_{8,y} = \sum_{a=4}^{7} \frac{N_{a,y} P_{8,y}}{P_{a,y}} \Big/ 4 .$$

Table 1. Nominal catches (t) of haddock from unit areas 5Zjm. For "others" it was assumed that 40% of the total 5Z catch was in 5Zjm.

| Year | Canada | USA | Others | Total |
|---|---|---|---|---|
| 1969 | 3941 | 6622 | 695 | 11258 |
| 1970 | 1970 | 3153 | 357 | 5480 |
| 1971 | 1610 | 3534 | 770 | 5914 |
| 1972 | 609 | 1551 | 502 | 2662 |
| 1973 | 1565 | 1396 | 396 | 3357 |
| 1974 | 462 | 955 | 573 | 2750[1] |
| 1975 | 1353 | 1705 | 29 | 3087 |
| 1976 | 1355 | 973 | 24 | 2352 |
| 1977 | 2871 | 2429 | 0 | 9174[1] |
| 1978 | 9968 | 4724 | 0 | 16269[1] |
| 1979 | 5080 | 5211 | 0 | 10291 |
| 1980 | 10017 | 5615 | 0 | 25036[1] |
| 1981 | 5658 | 9077 | 0 | 14735 |
| 1982 | 4872 | 6280 | 0 | 11152 |
| 1983 | 3208 | 4454 | 0 | 7662 |
| 1984 | 1463 | 5121 | 0 | 6583 |
| 1985 | 3484 | 1683 | 0 | 5167 |
| 1986 | 3415 | 2200 | 0 | 5615 |
| 1987 | 4703 | 1418 | 0 | 6121 |
| 1988 | 4046[2] | 1693 | 0 | 5739 |
| 1989 | 3059 | 787 | 0 | 3846 |
| 1990 | 3340 | 1189 | 0 | 4529 |
| 1991 | 5446 | 931 | 0 | 6377 |
| 1992 | 4061 | 1629 | 0 | 5690 |
| 1993 | 3727 | 421 | 0 | 4148 |
| 1994 | 2411 | 150[3] | 0 | 2561 |
| 1995 | 2064 | 100[3] | 0 | 2164 |

[1] Values augmented by 760t, 3874t, 1577t, and 9404t in 1974, 1977, 1978, and 1980, respectively, to account for USA discards

[2] 1895t excluded because of suspected area misreporting

[3] R. W. Brown pers. com.

Table 2. Canadian catch (t) of haddock in unit areas 5Zjm by gear category and tonnage class for principle gears.

| Year | Side | Otter Trawl Stern | | | | | Longline | | | Other | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | Total | 2 | 3 | Total | | |
| 1969 | 777 | 0 | 1 | 225 | 2902 | 3127 | 2 | 21 | 23 | 15 | 3941 |
| 1970 | 575 | 2 | 0 | 133 | 1179 | 1314 | 6 | 72 | 78 | 2 | 1970 |
| 1971 | 501 | 0 | 0 | 16 | 939 | 955 | 18 | 129 | 151 | 3 | 1610 |
| 1972 | 148 | 0 | 0 | 2 | 260 | 263 | 23 | 169 | 195 | 3 | 609 |
| 1973 | 633 | 0 | 0 | 60 | 766 | 826 | 23 | 80 | 105 | 0 | 1565 |
| 1974 | 27 | 0 | 6 | 8 | 332 | 346 | 29 | 59 | 88 | 1 | 462 |
| 1975 | 222 | 0 | 1 | 60 | 963 | 1024 | 25 | 81 | 107 | 0 | 1353 |
| 1976 | 217 | 0 | 2 | 59 | 905 | 967 | 48 | 108 | 156 | 15 | 1355 |
| 1977 | 370 | 92 | 243 | 18 | 2025 | 2378 | 43 | 51 | 94 | 28 | 2871 |
| 1978 | 2456 | 237 | 812 | 351 | 5639 | 7039 | 121 | 47 | 169 | 305 | 9968 |
| 1979 | 1622 | 136 | 858 | 627 | 1564 | 3185 | 190 | 80 | 271 | 2 | 5080 |
| 1980 | 1444 | 354 | 359 | 950 | 6254 | 7917 | 129 | 51 | 587 | 69 | 10017 |
| 1981 | 478 | 448 | 629 | 737 | 2344 | 4159 | 331 | 99 | 1019 | 2 | 5658 |
| 1982 | 115 | 189 | 318 | 187 | 3341 | 4045 | 497 | 187 | 712 | 0 | 4872 |
| 1983 | 106 | 615 | 431 | 107 | 1130 | 2283 | 593 | 195 | 815 | 4 | 3208 |
| 1984 | 5 | 180 | 269 | 21 | 149 | 620 | 614 | 192 | 835 | 3 | 1463 |
| 1985 | 72 | 840 | 1401 | 155 | 348 | 2745 | 562 | 33 | 626 | 41 | 3484 |
| 1986 | 51 | 829 | 1378 | 95 | 432 | 2734 | 475 | 98 | 594 | 35 | 3415 |
| 1987 | 48 | 782 | 1448 | 49 | 1241 | 3521 | 854 | 113 | 1046 | 89 | 4703 |
| 1988[1] | 72 | 1091 | 1456 | 186 | 398 | 3183 | 428 | 200 | 695 | 97 | 4046 |
| 1989 | 0 | 489 | 573 | 376 | 536 | 1976 | 713 | 175 | 977 | 106 | 3059 |
| 1990 | 0 | 928 | 890 | 116 | 471 | 2411 | 623 | 173 | 853 | 76 | 3340 |
| 1991 | 0 | 1610 | 1647 | 81 | 679 | 4018 | 900 | 271 | 1309 | 119 | 5446 |
| 1992 | 0 | 797 | 1084 | 56 | 645 | 2583 | 984 | 245 | 1384 | 90 | 4061 |
| 1993 | 0 | 535 | 1179 | 67 | 699 | 2490 | 794 | 156 | 1144 | 94 | 3727 |
| 1994 | 0 | 495 | 911 | 79 | 112 | 1597 | 498 | 47 | 714 | 100 | 2411 |
| 1995 | 0 | 510 | 896 | 14 | 214 | 1647 | 261 | 69 | 389 | 28 | 2064 |

[1] Catches of 26t, 776t, 1091t and 2t for side otter trawlers and stern otter trawlers tonnage classes 2, 3 and 5 respectively were excluded because of suspected area misreporting.

Table 3. Monthly catch (t) of haddock by Canada in unit areas 5Zjm.

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1969 | 105 | 74 | 6 | 291 | 588 | 691 | 559 | 580 | 551 | 360 | 102 | 34 | 3941 |
| 1970 | 2 | 105 | 0 | 1 | 574 | 345 | 103 | 456 | 242 | 103 | 26 | 12 | 1970 |
| 1971 | 0 | 9 | 1 | 0 | 400 | 132 | 283 | 278 | 97 | 246 | 141 | 21 | 1610 |
| 1972 | 0 | 119 | 2 | 0 | 2 | 111 | 84 | 116 | 98 | 68 | 7 | 2 | 609 |
| 1973 | 4 | 10 | 0 | 0 | 0 | 184 | 198 | 572 | 339 | 232 | 22 | 4 | 1565 |
| 1974 | 19 | 0 | 1 | 0 | 0 | 58 | 63 | 53 | 96 | 61 | 92 | 19 | 462 |
| 1975 | 4 | 14 | 0 | 0 | 0 | 166 | 256 | 482 | 100 | 166 | 118 | 45 | 1353 |
| 1976 | 0 | 7 | 62 | 68 | 60 | 587 | 152 | 190 | 186 | 26 | 9 | 7 | 1355 |
| 1977 | 102 | 177 | 7 | 0 | 23 | 519 | 1059 | 835 | 13 | 59 | 56 | 22 | 2871 |
| 1978 | 104 | 932 | 44 | 22 | 21 | 319 | 405 | 85 | 642 | 5433 | 1962 | 0 | 9968 |
| 1979 | 123 | 898 | 400 | 175 | 69 | 1393 | 885 | 396 | 406 | 261 | 53 | 22 | 5080 |
| 1980 | 38 | 134 | 14 | 29 | 223 | 2956 | 2300 | 965 | 1411 | 1668 | 104 | 176 | 10017 |
| 1981 | 38 | 481 | 568 | 4 | 254 | 1357 | 1241 | 726 | 292 | 82 | 378 | 239 | 5658 |
| 1982 | 129 | 309 | 1 | 11 | 46 | 1060 | 769 | 682 | 585 | 837 | 398 | 44 | 4872 |
| 1983 | 32 | 67 | 29 | 47 | 60 | 1288 | 387 | 483 | 526 | 195 | 88 | 6 | 3208 |
| 1984 | 3 | 5 | 81 | 88 | 73 | 433 | 219 | 254 | 211 | 71 | 25 | 0 | 1463 |
| 1985 | 1 | 11 | 33 | 99 | 26 | 354 | 392 | 1103 | 718 | 594 | 61 | 93 | 3484 |
| 1986 | 11 | 28 | 79 | 99 | 40 | 1339 | 1059 | 369 | 233 | 139 | 12 | 8 | 3415 |
| 1987 | 24 | 26 | 138 | 70 | 12 | 1762 | 1383 | 665 | 405 | 107 | 97 | 14 | 4703 |
| 1988[1] | 39 | 123 | 67 | 79 | 15 | 1816 | 1360 | 315 | 130 | 65 | 13 | 24 | 4046 |
| 1989 | 32 | 94 | 48 | 7 | 20 | 1398 | 356 | 566 | 141 | 272 | 108 | 18 | 3059 |
| 1990 | 35 | 14 | 50 | 0 | 7 | 1179 | 668 | 678 | 469 | 199 | 18 | 22 | 3340 |
| 1991 | 144 | 166 | 49 | 26 | 21 | 1928 | 1004 | 705 | 566 | 576 | 123 | 137 | 5446 |
| 1992 | 118 | 205 | 97 | 152 | 36 | 1381 | 619 | 414 | 398 | 401 | 209 | 28 | 4061 |
| 1993 | 466 | 690 | 96 | 78 | 25 | 723 | 505 | 329 | 202 | 198 | 230 | 185 | 3727 |
| 1994 | 1 | 3 | 1 | 2 | 0 | 398 | 693 | 373 | 375 | 220 | 211 | 134 | 2411 |
| 1995 | 1 | 1 | 1 | 1 | 0 | 762 | 326 | 290 | 281 | 109 | 197 | 96 | 2064 |

[1] Catches of 3t, 1846t and 46t for Jan., Feb., and Mar., respectively for otter trawlers were excluded because of suspected area misreporting

Table 4. USA catch (t) of haddock (excluding discard estimates) in unit areas 5Zjm by gear category and tonnage class.

| Year | Otter Trawl | | | Other | Total |
|---|---|---|---|---|---|
| | 3 | 4 | Total | | |
| 1969 | 3010 | 3610 | 6621 | 0 | 6622 |
| 1970 | 1602 | 1551 | 3154 | 0 | 3153 |
| 1971 | 1760 | 1768 | 3533 | 0 | 3534 |
| 1972 | 861 | 690 | 1551 | 0 | 1551 |
| 1973 | 637 | 759 | 1396 | 0 | 1396 |
| 1974 | 443 | 512 | 955 | 0 | 955 |
| 1975 | 993 | 675 | 1668 | 36 | 1705 |
| 1976 | 671 | 302 | 972 | 2 | 973 |
| 1977 | 1721 | 700 | 2423 | 5 | 2429 |
| 1978 | 3140 | 1573 | 4713 | 11 | 4724 |
| 1979 | 3281 | 1927 | 5208 | 4 | 5211 |
| 1980 | 3654 | 2955 | 5611 | 4 | 5615 |
| 1981 | 3591 | 5408 | 9031 | 45 | 9077 |
| 1982 | 2585 | 3657 | 6242 | 37 | 6280 |
| 1983 | 1162 | 3261 | 4423 | 29 | 4454 |
| 1984 | 1854 | 3260 | 5115 | 5 | 5121 |
| 1985 | 856 | 823 | 1679 | 4 | 1683 |
| 1986 | 985 | 1207 | 2192 | 9 | 2200 |
| 1987 | 778 | 639 | 1417 | 1 | 1418 |
| 1988 | 920 | 768 | 1688 | 6 | 1693 |
| 1989 | 359 | 419 | 780 | 6 | 787 |
| 1990 | 486 | 688 | 1178 | 4 | 1189 |
| 1991 | 400 | 517 | 918 | 13 | 931 |
| 1992 | 597 | 740 | 1337 | 292 | 1629 |
| 1993 | 142 | 191 | 333 | 88 | 421 |
| 1994 | | | n/a | | 150[1] |
| 1995 | | | n/a | | 100[1] |

[1] R. W. Brown pers. com.

Table 5. Monthly catch (t) of haddock (excluding discard estimates) by USA in unit areas 5Zjm.

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1969 | 525 | 559 | 976 | 1825 | 670 | 809 | 204 | 219 | 249 | 226 | 203 | 157 | 6622 |
| 1970 | 169 | 219 | 242 | 375 | 608 | 374 | 324 | 333 | 179 | 219 | 61 | 50 | 3153 |
| 1971 | 155 | 361 | 436 | 483 | 668 | 503 | 338 | 152 | 147 | 165 | 58 | 68 | 3534 |
| 1972 | 150 | 196 | 91 | 90 | 239 | 261 | 97 | 164 | 84 | 63 | 52 | 64 | 1551 |
| 1973 | 90 | 111 | 77 | 85 | 138 | 365 | 217 | 196 | 37 | 3 | 22 | 55 | 1396 |
| 1974 | 135 | 70 | 47 | 70 | 122 | 160 | 165 | 43 | 27 | 6 | 19 | 91 | 955 |
| 1975 | 152 | 123 | 32 | 116 | 388 | 489 | 138 | 95 | 57 | 24 | 52 | 39 | 1705 |
| 1976 | 116 | 147 | 83 | 106 | 323 | 162 | 7 | 6 | 5 | 2 | 3 | 13 | 973 |
| 1977 | 75 | 211 | 121 | 154 | 374 | 372 | 434 | 191 | 73 | 52 | 146 | 226 | 2429 |
| 1978 | 336 | 437 | 263 | 584 | 752 | 750 | 467 | 221 | 245 | 426 | 194 | 49 | 4724 |
| 1979 | 274 | 329 | 352 | 548 | 766 | 816 | 588 | 659 | 224 | 202 | 281 | 172 | 5211 |
| 1980 | 632 | 1063 | 742 | 784 | 711 | 461 | 324 | 254 | 221 | 91 | 110 | 222 | 5615 |
| 1981 | 550 | 1850 | 634 | 627 | 882 | 1326 | 1233 | 873 | 321 | 284 | 242 | 255 | 9077 |
| 1982 | 425 | 754 | 502 | 347 | 718 | 1801 | 757 | 145 | 201 | 216 | 276 | 138 | 6280 |
| 1983 | 492 | 931 | 272 | 181 | 310 | 1145 | 231 | 178 | 187 | 110 | 227 | 190 | 4454 |
| 1984 | 540 | 961 | 366 | 281 | 627 | 1047 | 370 | 302 | 250 | 196 | 92 | 89 | 5121 |
| 1985 | 165 | 190 | 254 | 300 | 352 | 206 | 60 | 47 | 1 | 24 | 41 | 43 | 1683 |
| 1986 | 184 | 396 | 334 | 479 | 496 | 221 | 31 | 6 | 12 | 6 | 6 | 29 | 2200 |
| 1987 | 225 | 52 | 43 | 307 | 233 | 342 | 67 | 30 | 24 | 4 | 23 | 68 | 1418 |
| 1988 | 196 | 152 | 207 | 245 | 366 | 316 | 30 | 19 | 6 | 1 | 45 | 110 | 1693 |
| 1989 | 114 | 56 | 47 | 164 | 161 | 145 | 15 | 8 | 1 | 5 | 25 | 46 | 787 |
| 1990 | 148 | 21 | 155 | 274 | 214 | 306 | 23 | 3 | 5 | 5 | 16 | 19 | 1189 |
| 1991 | 105 | 28 | 76 | 133 | 89 | 434 | 1 | 20 | 6 | 0 | 19 | 19 | 931 |
| 1992 | 253 | 81 | 51 | 149 | 353 | 669 | 20 | 20 | 17 | 3 | 2 | 12 | 1629 |
| 1993 | 15 | 12 | 16 | 55 | 84 | 209 | 6 | 3 | 3 | 7 | 2 | 8 | 421 |
| 1994 | | | | | | | | | | | | n/a | 150[1] |
| 1995 | | | | | | | | | | | | n/a | 100[1] |

[1] R. W. Brown pers. com

Table 6. Canadian commercial catch-at-age numbers (000's) of haddock from unit areas 5Zjm.

| Year | Age Group | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9+ | Total |
| 1969 | 0 | 7 | 558 | 101 | 105 | 963 | 275 | 28 | 89 | 2127 |
| 1970 | 4 | 35 | 3 | 129 | 57 | 46 | 410 | 131 | 60 | 875 |
| 1971 | 0 | 491 | 71 | 6 | 67 | 41 | 33 | 173 | 84 | 968 |
| 1972 | 90 | 0 | 88 | 19 | 5 | 16 | 6 | 3 | 85 | 312 |
| 1973 | 107 | 829 | 1 | 188 | 15 | 3 | 18 | 3 | 49 | 1213 |
| 1974 | 0 | 240 | 66 | 0 | 10 | 1 | 0 | 9 | 16 | 341 |
| 1975 | 0 | 117 | 620 | 91 | 2 | 16 | 0 | 1 | 14 | 863 |
| 1976 | 53 | 119 | 120 | 391 | 57 | 0 | 7 | 0 | 10 | 757 |
| 1977 | 0 | 2398 | 34 | 63 | 94 | 46 | 0 | 3 | 1 | 2639 |
| 1978 | 1 | 250 | 5865 | 97 | 55 | 98 | 35 | 1 | 2 | 6404 |
| 1979 | 0 | 14 | 99 | 2196 | 136 | 70 | 56 | 11 | 2 | 2585 |
| 1980 | 2 | 8608 | 305 | 130 | 668 | 58 | 15 | 11 | 5 | 9802 |
| 1981 | 0 | 243 | 2279 | 140 | 275 | 390 | 38 | 3 | 18 | 3386 |
| 1982 | 0 | 313 | 469 | 1400 | 93 | 106 | 195 | 9 | 5 | 2590 |
| 1983 | 0 | 161 | 359 | 258 | 679 | 76 | 34 | 89 | 4 | 1660 |
| 1984 | 0 | 12 | 38 | 63 | 52 | 172 | 61 | 33 | 104 | 535 |
| 1985 | 0 | 2022 | 305 | 114 | 89 | 55 | 87 | 22 | 62 | 2755 |
| 1986 | 6 | 38 | 1701 | 86 | 70 | 52 | 29 | 40 | 21 | 2042 |
| 1987 | 0 | 1986 | 90 | 1088 | 59 | 32 | 30 | 28 | 68 | 3381 |
| 1988 | 4 | 51 | 1878 | 81 | 390 | 53 | 7 | 16 | 86 | 2566 |
| 1989 | 0 | 1132 | 68 | 623 | 64 | 202 | 13 | 8 | 37 | 2146 |
| 1990 | 2 | 6 | 1070 | 55 | 501 | 14 | 122 | 29 | 34 | 1833 |
| 1991 | 6 | 429 | 62 | 1809 | 50 | 297 | 28 | 123 | 57 | 2861 |
| 1992 | 7 | 230 | 237 | 62 | 1020 | 14 | 212 | 3 | 86 | 1871 |
| 1993 | 7 | 246 | 319 | 245 | 69 | 551 | 7 | 143 | 69 | 1656 |
| 1994 | 0 | 210 | 703 | 137 | 49 | 33 | 107 | 13 | 37 | 1289 |
| 1995 | 1 | 57 | 502 | 407 | 52 | 25 | 2 | 51 | 15 | 1112 |

Table 7. Average weight-at-age (kg) of haddock from the Canadian commercial fishery in unit areas 5Zjm.

| Year | Age Group | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1969 | - | 0.766 | 1.324 | 1.513 | 1.679 | 1.887 | 2.364 | 2.807 |
| 1970 | 0.721 | 1.062 | 0.812 | 1.653 | 1.905 | 2.137 | 2.201 | 2.855 |
| 1971 | - | 0.950 | 1.147 | 1.284 | 2.141 | 2.346 | 2.274 | 2.684 |
| 1972 | 0.759 | - | 1.703 | 1.820 | 2.209 | 2.624 | 2.469 | 2.792 |
| 1973 | 0.683 | 1.054 | 1.367 | 1.789 | 2.296 | 1.760 | 3.003 | 3.097 |
| 1974 | - | 1.025 | 1.449 | - | 1.995 | 3.760 | - | 3.145 |
| 1975 | - | 0.868 | 1.544 | 2.096 | 1.997 | 2.425 | 4.114 | 3.557 |
| 1976 | 0.596 | 0.996 | 1.351 | 2.076 | 2.808 | - | 3.251 | - |
| 1977 | - | 0.964 | 1.466 | 1.871 | 2.500 | 3.035 | - | 3.502 |
| 1978 | 0.619 | 1.168 | 1.505 | 2.186 | 3.100 | 3.290 | 3.188 | 3.364 |
| 1979 | - | 1.024 | 1.364 | 1.991 | 2.387 | 2.920 | 3.353 | 3.383 |
| 1980 | 0.405 | 0.888 | 1.032 | 1.792 | 2.294 | 2.593 | 3.948 | 3.803 |
| 1981 | - | 0.915 | 1.391 | 1.721 | 2.383 | 2.822 | 3.698 | 5.013 |
| 1982 | - | 1.056 | 1.556 | 1.915 | 2.348 | 2.801 | 2.909 | 3.414 |
| 1983 | - | 1.031 | 1.401 | 1.822 | 2.200 | 2.543 | 2.821 | 3.007 |
| 1984 | - | 0.883 | 1.401 | 2.010 | 2.257 | 2.770 | 2.918 | 3.326 |
| 1985 | - | 0.948 | 1.264 | 2.068 | 2.169 | 2.942 | 3.289 | 3.238 |
| 1986 | 0.452 | 0.981 | 1.458 | 2.104 | 2.913 | 2.899 | 3.646 | 4.248 |
| 1987 | - | 0.832 | 1.391 | 2.073 | 2.253 | 2.598 | 2.906 | 3.623 |
| 1988 | 0.421 | 0.974 | 1.315 | 1.787 | 2.234 | 2.264 | 2.978 | 3.036 |
| 1989 | - | 0.861 | 1.449 | 1.789 | 2.215 | 2.604 | 2.795 | 3.014 |
| 1990 | 0.639 | 0.956 | 1.461 | 1.711 | 2.232 | 2.281 | 2.736 | 2.396 |
| 1991 | 0.581 | 1.204 | 1.220 | 1.838 | 2.023 | 2.630 | 2.341 | 2.891 |
| 1992 | 0.538 | 1.163 | 1.687 | 1.694 | 2.264 | 2.073 | 2.977 | 2.633 |
| 1993 | 0.659 | 1.160 | 1.750 | 2.236 | 2.113 | 2.677 | 2.987 | 3.133 |
| 1994 | 0.405 | 1.141 | 1.669 | 2.246 | 2.664 | 2.439 | 2.835 | 3.240 |
| 1995 | 0.797 | 1.047 | 1.513 | 2.038 | 2.554 | 2.761 | 2.916 | 3.011 |

Table 8. USA commercial catch-at-age numbers (000's) of haddock from unit areas 5Zjm.

| Year | Age Group | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9+ | Total |
| 1969 | 0 | 10 | 818 | 145 | 207 | 1739 | 489 | 53 | 175 | 3636 |
| 1970 | 9 | 42 | 4 | 199 | 82 | 71 | 657 | 212 | 111 | 1387 |
| 1971 | 0 | 566 | 155 | 23 | 150 | 102 | 112 | 462 | 269 | 1837 |
| 1972 | 125 | 0 | 235 | 42 | 13 | 55 | 27 | 8 | 248 | 754 |
| 1973 | 42 | 662 | 5 | 155 | 20 | 6 | 17 | 5 | 104 | 1015 |
| 1974 | 0 | 552 | 133 | 0 | 20 | 2 | 0 | 18 | 33 | 757 |
| 1975 | 0 | 65 | 784 | 144 | 4 | 29 | 1 | 2 | 24 | 1053 |
| 1976 | 0 | 28 | 53 | 421 | 62 | 0 | 9 | 0 | 11 | 584 |
| 1977 | 0 | 1307 | 30 | 115 | 211 | 117 | 0 | 12 | 13 | 1806 |
| 1978 | 0 | 39 | 2770 | 63 | 115 | 201 | 46 | 9 | 7 | 3249 |
| 1979 | 0 | 8 | 103 | 2207 | 189 | 112 | 138 | 28 | 11 | 2795 |
| 1980 | 0 | 911 | 46 | 175 | 1722 | 134 | 113 | 41 | 7 | 3149 |
| 1981 | 0 | 419 | 4313 | 244 | 310 | 830 | 84 | 27 | 6 | 6234 |
| 1982 | 0 | 401 | 579 | 1409 | 103 | 273 | 529 | 53 | 60 | 3406 |
| 1983 | 0 | 44 | 223 | 254 | 973 | 146 | 74 | 324 | 28 | 2065 |
| 1984 | 0 | 67 | 214 | 285 | 204 | 890 | 135 | 127 | 227 | 2149 |
| 1985 | 0 | 41 | 70 | 62 | 101 | 68 | 284 | 30 | 52 | 708 |
| 1986 | 0 | 0 | 856 | 87 | 72 | 71 | 89 | 133 | 19 | 1327 |
| 1987 | 0 | 5 | 37 | 427 | 37 | 24 | 52 | 40 | 40 | 661 |
| 1988 | 0 | 0 | 267 | 40 | 487 | 56 | 29 | 30 | 12 | 921 |
| 1989 | 0 | 21 | 10 | 111 | 66 | 118 | 18 | 13 | 7 | 364 |
| 1990 | 0 | 1 | 195 | 71 | 241 | 54 | 41 | 13 | 8 | 624 |
| 1991 | 0 | 12 | 27 | 232 | 39 | 92 | 45 | 22 | 3 | 472 |
| 1992 | 0 | 0 | 74 | 65 | 426 | 75 | 103 | 22 | 3 | 768 |
| 1993 | 0 | 1 | 24 | 35 | 17 | 84 | 26 | 10 | 5 | 202 |
| 1994[1] | 0 | 6 | 34 | 10 | 5 | 2 | 15 | 0 | 4 | 77 |
| 1995[1] | 0 | 1 | 22 | 20 | 3 | 2 | 0 | 3 | 1 | 52 |

[1] Estimated using Canadian otter trawler, quarter 2 age composition.

Table 9. Average weight-at-age (kg) of haddock from the USA commercial fishery in unit areas 5Zjm.

| Year | Age Group | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1969 | - | 0.760 | 1.253 | 1.543 | 1.633 | 1.807 | 2.261 | 2.918 |
| 1970 | 0.721 | 1.071 | 0.813 | 1.653 | 1.873 | 2.116 | 2.198 | 2.833 |
| 1971 | - | 0.909 | 1.018 | 1.269 | 1.952 | 2.218 | 2.258 | 2.586 |
| 1972 | 0.759 | - | 1.509 | 1.719 | 2.125 | 2.470 | 2.397 | 2.414 |
| 1973 | 0.683 | 0.937 | 1.367 | 1.823 | 2.133 | 1.573 | 2.758 | 3.398 |
| 1974 | - | 0.946 | 1.402 | - | 1.979 | 3.760 | - | 3.120 |
| 1975 | - | 0.878 | 1.508 | 2.041 | 1.997 | 2.420 | 4.114 | 3.557 |
| 1976 | - | 0.785 | 1.163 | 1.654 | 2.057 | - | 2.293 | - |
| 1977 | - | 0.981 | 1.414 | 1.776 | 2.264 | 2.720 | - | 3.007 |
| 1978 | - | 1.043 | 1.280 | 1.852 | 2.397 | 2.737 | 2.808 | 2.745 |
| 1979 | - | 0.920 | 1.235 | 1.719 | 2.076 | 2.735 | 3.164 | 3.233 |
| 1980 | - | 0.929 | 1.050 | 1.640 | 2.045 | 2.593 | 3.481 | 3.553 |
| 1981 | - | 0.876 | 1.194 | 1.518 | 2.170 | 2.511 | 3.418 | 3.882 |
| 1982 | - | 0.894 | 1.207 | 1.657 | 2.308 | 2.463 | 2.976 | 3.551 |
| 1983 | - | 1.001 | 1.245 | 1.678 | 2.061 | 2.491 | 2.906 | 3.130 |
| 1984 | - | 0.875 | 1.345 | 1.801 | 2.134 | 2.573 | 2.828 | 3.084 |
| 1985 | - | 1.049 | 1.081 | 1.635 | 2.278 | 2.509 | 2.745 | 3.138 |
| 1986 | - | - | 1.142 | 1.630 | 1.830 | 2.576 | 2.749 | 3.367 |
| 1987 | - | 1.118 | 1.529 | 1.758 | 1.978 | 2.588 | 2.980 | 3.661 |
| 1988 | - | 1.160 | 1.239 | 1.546 | 1.888 | 2.431 | 3.019 | 3.449 |
| 1989 | - | 1.246 | 1.455 | 1.706 | 2.152 | 2.381 | 3.170 | 3.650 |
| 1990 | - | 1.416 | 1.184 | 1.846 | 1.953 | 2.570 | 3.016 | 4.288 |
| 1991 | - | 0.939 | 1.288 | 1.515 | 2.169 | 2.485 | 3.276 | 3.687 |
| 1992 | - | 1.311 | 1.417 | 1.616 | 1.946 | 2.573 | 3.011 | 3.505 |
| 1993 | - | 1.044 | 1.395 | 1.794 | 1.772 | 2.273 | 2.217 | 2.825 |
| 1994[1] | - | 0.923 | 1.491 | 2.091 | 2.395 | 2.146 | 2.805 | 2.593 |
| 1995[1] | - | 0.964 | 1.506 | 1.958 | 2.476 | 2.657 | - | 3.308 |

[1] Esumated

Table 10. Total[1] commercial catch-at-age numbers (000's) of haddock from unit areas 5Zjm.

| Year | Age Group | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9+ | Total |
| 1969 | 0 | 19 | 1449 | 262 | 333 | 2881 | 816 | 88 | 280 | 6128 |
| 1970 | 25 | 83 | 7 | 350 | 148 | 127 | 1140 | 366 | 184 | 2431 |
| 1971 | 0 | 1219 | 261 | 32 | 249 | 163 | 166 | 748 | 404 | 3242 |
| 1972 | 281 | 1 | 398 | 75 | 22 | 87 | 42 | 13 | 418 | 1336 |
| 1973 | 1015 | 1728 | 7 | 360 | 37 | 10 | 37 | 8 | 161 | 3363 |
| 1974 | 17 | 2080[2] | 272 | 0 | 40 | 3 | 0 | 35 | 69 | 2517 |
| 1975 | 0 | 184 | 1418 | 237 | 6 | 46 | 1 | 3 | 39 | 1935 |
| 1976 | 67 | 148 | 175 | 818 | 121 | 0 | 16 | 0 | 21 | 1367 |
| 1977 | 0 | 7623[2] | 65 | 178 | 305 | 163 | 0 | 15 | 14 | 8362 |
| 1978 | 1 | 289 | 9832[2] | 160 | 169 | 299 | 81 | 10 | 9 | 10850 |
| 1979 | 0 | 22 | 202 | 4403 | 325 | 182 | 195 | 39 | 13 | 5380 |
| 1980 | 2 | 9519 | 351 | 305 | 2391 | 192 | 128 | 52 | 12 | 12951 |
| 1981 | 0 | 661 | 6593 | 384 | 585 | 1220 | 121 | 31 | 24 | 9619 |
| 1982 | 0 | 714 | 1048 | 2809 | 196 | 379 | 724 | 62 | 65 | 5997 |
| 1983 | 0 | 205 | 582 | 512 | 1652 | 221 | 108 | 413 | 32 | 3725 |
| 1984 | 0 | 79 | 252 | 348 | 256 | 1062 | 196 | 160 | 331 | 2684 |
| 1985 | 0 | 2063 | 374 | 176 | 189 | 123 | 371 | 53 | 114 | 3463 |
| 1986 | 6 | 38 | 2557 | 173 | 142 | 122 | 118 | 173 | 40 | 3368 |
| 1987 | 0 | 1990 | 127 | 1515 | 96 | 56 | 82 | 68 | 108 | 4042 |
| 1988 | 4 | 51 | 2145 | 121 | 877 | 109 | 36 | 46 | 98 | 3487 |
| 1989 | 0 | 1153 | 78 | 734 | 129 | 320 | 31 | 20 | 44 | 2510 |
| 1990 | 2 | 7 | 1265 | 126 | 743 | 68 | 163 | 42 | 42 | 2457 |
| 1991 | 6 | 441 | 89 | 2041 | 88 | 389 | 72 | 145 | 60 | 3332 |
| 1992 | 7 | 230 | 311 | 127 | 1446 | 89 | 315 | 26 | 89 | 2639 |
| 1993 | 7 | 247 | 343 | 279 | 85 | 635 | 34 | 153 | 74 | 1857 |
| 1994 | 0 | 217 | 738 | 148 | 54 | 35 | 123 | 14 | 41 | 1368 |
| 1995 | 1 | 58 | 524 | 427 | 55 | 27 | 2 | 54 | 16 | 1164 |

[1] Prior to 1977 total catch includes small mesh foreign fishery.

[2] Includes discard estimates based on trip interviews.

Table 11. Average weight-at-age (kg) of haddock from the commercial fishery in unit areas 5Zjm.

| Year | Age Group | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1969 | 0.600 | 0.763 | 1.282 | 1.531 | 1.649 | 1.836 | 2.298 | 2.879 |
| 1970 | 0.721 | 1.067 | 0.812 | 1.653 | 1.886 | 2.124 | 2.199 | 2.841 |
| 1971 | 0.600 | 0.928 | 1.059 | 1.272 | 2.011 | 2.255 | 2.262 | 2.613 |
| 1972 | 0.759 | 1.000 | 1.562 | 1.750 | 2.147 | 2.505 | 2.411 | 2.514 |
| 1973 | 0.683 | 1.002 | 1.367 | 1.804 | 2.202 | 1.631 | 2.885 | 3.295 |
| 1974 | 0.600 | 0.970 | 1.418 | 1.800 | 1.984 | 3.760 | 2.700 | 3.128 |
| 1975 | 0.600 | 0.872 | 1.524 | 2.062 | 1.997 | 2.422 | 4.114 | 3.557 |
| 1976 | 0.596 | 0.956 | 1.293 | 1.857 | 2.417 | 2.700 | 2.702 | 3.000 |
| 1977 | 0.600 | 0.970 | 1.442 | 1.809 | 2.337 | 2.809 | 2.700 | 3.095 |
| 1978 | 0.619 | 1.151 | 1.433 | 2.055 | 2.623 | 2.919 | 2.972 | 2.829 |
| 1979 | 0.600 | 0.987 | 1.298 | 1.805 | 2.206 | 2.806 | 3.219 | 3.277 |
| 1980 | 0.405 | 0.892 | 1.034 | 1.705 | 2.115 | 2.593 | 3.535 | 3.608 |
| 1981 | 0.600 | 0.890 | 1.262 | 1.592 | 2.270 | 2.611 | 3.505 | 4.009 |
| 1982 | 0.600 | 0.965 | 1.363 | 1.786 | 2.327 | 2.557 | 2.958 | 3.531 |
| 1983 | 0.600 | 1.024 | 1.341 | 1.750 | 2.118 | 2.509 | 2.879 | 3.104 |
| 1984 | 0.600 | 0.876 | 1.354 | 1.838 | 2.159 | 2.605 | 2.856 | 3.134 |
| 1985 | 0.600 | 0.950 | 1.230 | 1.915 | 2.227 | 2.702 | 2.872 | 3.180 |
| 1986 | 0.452 | 0.981 | 1.352 | 1.866 | 2.367 | 2.712 | 2.969 | 3.570 |
| 1987 | 0.600 | 0.833 | 1.431 | 1.984 | 2.148 | 2.594 | 2.953 | 3.646 |
| 1988 | 0.421 | 0.974 | 1.305 | 1.708 | 2.042 | 2.350 | 3.011 | 3.305 |
| 1989 | 0.600 | 0.868 | 1.450 | 1.777 | 2.183 | 2.522 | 3.012 | 3.411 |
| 1990 | 0.639 | 0.999 | 1.419 | 1.787 | 2.141 | 2.509 | 2.807 | 3.002 |
| 1991 | 0.581 | 1.197 | 1.241 | 1.802 | 2.087 | 2.596 | 2.918 | 3.012 |
| 1992 | 0.538 | 1.163 | 1.622 | 1.654 | 2.171 | 2.491 | 2.988 | 3.388 |
| 1993 | 0.659 | 1.160 | 1.724 | 2.181 | 2.047 | 2.623 | 2.386 | 3.112 |
| 1994 | 0.405 | 1.135 | 1.661 | 2.235 | 2.639 | 2.422 | 2.831 | 3.223 |
| 1995 | 0.797 | 1.045 | 1.513 | 2.034 | 2.550 | 2.751 | 2.916 | 3.027 |

Table 12. Vessel and door used in the spring survey on Georges Bank with respective conversion coefficients (from O'Brien and Brown 1996).

| Year(s) | Vessel | Conversion Coefficient | Door | Conversion Coefficient |
|---|---|---|---|---|
| 1968-80 | ALBATROSS IV | 1.00 | BMV | 1.49 |
| 1981-82 | DELAWARE II | 0.82 | BMV | 1.49 |
| 1983-84 | ALBATROSS IV | 1.00 | BMV | 1.49 |
| 1985-88 | ALBATROSS IV | 1.00 | POLY | 1.00 |
| 1989-91 | DELAWARE II | 0.82 | POLY | 1.00 |
| 1992-93 | ALBATROSS IV | 1.00 | POLY | 1.00 |
| 1994 | DELAWARE II | 0.82 | POLY | 1.00 |
| 1995 | ALBATROSS IV | 1.00 | POLY | 1.00 |

Table 13. Vessel and door used in the fall survey on Georges Bank with respective conversion coefficients (from O'Brien and Brown 1996).

| Year(s) | Vessel | Conversion Coefficient | Door | Conversion Coefficient |
|---|---|---|---|---|
| 1963-76 | ALBATROSS IV | 1.00 | BMV | 1.49 |
| 1977-81 | DELAWARE II | 0.82 | BMV | 1.49 |
| 1982-84 | ALBATROSS IV | 1.00 | BMV | 1.49 |
| 1985-88 | ALBATROSS IV | 1.00 | POLY | 1.00 |
| 1989-91 | DELAWARE II | 0.82 | POLY | 1.00 |
| 1992 | ALBATROSS IV | 1.00 | POLY | 1.00 |
| 1993 | DELAWARE II | 0.82 | POLY | 1.00 |
| 1994-95 | ALBATROSS IV | 1.00 | POLY | 1.00 |

Table 14. Total estimated abundance-at-age numbers (000's) of haddock from unit areas 5Zjm from the Canadian spring surveys.

| Year | Age Group | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9+ | Total |
| 1986 | 5057 | 306 | 8175 | 997 | 189 | 348 | 305 | 425 | 401 | 16205 |
| 1987 | 46 | 4286 | 929 | 3450 | 653 | 81 | 387 | 135 | 1132 | 11099 |
| 1988 | 971 | 49 | 12714 | 257 | 4345 | 274 | 244 | 130 | 686 | 19671 |
| 1989 | 48 | 6664 | 991 | 2910 | 247 | 528 | 40 | 36 | 260 | 11725 |
| 1990 | 726 | 108 | 12302 | 166 | 4465 | 299 | 1370 | 144 | 389 | 19968 |
| 1991 | 393 | 2159 | 137 | 10876 | 116 | 1899 | 119 | 507 | 225 | 16431 |
| 1992 | 1914 | 3879 | 1423 | 221 | 4810 | 18 | 1277 | 52 | 655 | 14248 |
| 1993 | 3448 | 1759 | 545 | 431 | 34 | 1186 | 19 | 281 | 147 | 7849 |
| 1994 | 4197 | 15163 | 5332 | 549 | 314 | 20 | 915 | 18 | 356 | 26864 |
| 1995 | 1231 | 3224 | 6236 | 3034 | 720 | 398 | 0 | 729 | 849 | 16422 |
| 1996 | 1477 | 2059 | 4784 | 5247 | 3391 | 326 | 246 | 20 | 698 | 18247 |

Table 15. Total estimated abundance-at-age numbers (000's) of haddock in unit areas 5Zjm from the spring USA surveys. From 1973-81 a 41 Yankee trawl was used while a 36 Yankee was used in other years. Conversion factors to adjust for changes in door type and survey vessel were applied.

| Year | Age Group | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9+ | Total |
| 1968 | 0 | 3254 | 67 | 679 | 4853 | 2046 | 240 | 124 | 234 | 11497 |
| 1969 | 17 | 35 | 614 | 235 | 523 | 3232 | 1220 | 358 | 489 | 6724 |
| 1970 | 478 | 190 | 0 | 560 | 998 | 441 | 3169 | 2507 | 769 | 9113 |
| 1971 | 0 | 655 | 261 | 0 | 144 | 102 | 58 | 1159 | 271 | 2650 |
| 1972 | 2594 | 0 | 771 | 132 | 25 | 47 | 211 | 27 | 1214 | 5019 |
| 1973 | 2455 | 5639 | 0 | 1032 | 154 | 0 | 276 | 0 | 1208 | 10763 |
| 1974 | 1323 | 20596 | 4084 | 0 | 354 | 0 | 43 | 72 | 322 | 26795 |
| 1975 | 528 | 567 | 6016 | 1063 | 0 | 218 | 127 | 45 | 208 | 8773 |
| 1976 | 8279 | 402 | 433 | 1229 | 582 | 0 | 0 | 0 | 22 | 10948 |
| 1977 | 138 | 25922 | 294 | 855 | 816 | 586 | 0 | 22 | 98 | 28730 |
| 1978 | 0 | 743 | 20859 | 641 | 880 | 1163 | 89 | 23 | 116 | 24516 |
| 1979 | 10496 | 441 | 1313 | 9764 | 475 | 72 | 445 | 42 | 9 | 23057 |
| 1980 | 4364 | 67961 | 1129 | 1117 | 5822 | 628 | 381 | 705 | 359 | 82466 |
| 1981 | 3595 | 3041 | 27694 | 2887 | 719 | 2389 | 335 | 57 | 21 | 40738 |
| 1982 | 584 | 3697 | 1649 | 7743 | 745 | 447 | 669 | 0 | 0 | 15534 |
| 1983 | 238 | 770 | 686 | 359 | 2591 | 30 | 0 | 798 | 57 | 5529 |
| 1984 | 1366 | 1415 | 996 | 1001 | 936 | 1245 | 138 | 89 | 470 | 7656 |
| 1985 | 40 | 8911 | 1396 | 674 | 1496 | 588 | 1995 | 127 | 483 | 15709 |
| 1986 | 3334 | 280 | 3597 | 246 | 210 | 333 | 235 | 560 | 159 | 8953 |
| 1987 | 122 | 5480 | 144 | 1394 | 157 | 231 | 116 | 370 | 0 | 8013 |
| 1988 | 305 | 61 | 1868 | 235 | 611 | 203 | 218 | 178 | 0 | 3678 |
| 1989 | 84 | 6665 | 619 | 1343 | 267 | 791 | 58 | 92 | 47 | 9966 |
| 1990 | 1654 | 70 | 10338 | 598 | 1042 | 110 | 182 | 0 | 0 | 13995 |
| 1991 | 740 | 2071 | 432 | 3381 | 192 | 203 | 66 | 87 | 25 | 7198 |
| 1992 | 529 | 287 | 214 | 141 | 609 | 32 | 46 | 46 | 0 | 1905 |
| 1993 | 1870 | 1116 | 197 | 232 | 195 | 717 | 77 | 35 | 43 | 4481 |
| 1994 | 1025 | 4272 | 1487 | 269 | 184 | 118 | 278 | 28 | 85 | 7745 |
| 1995 | 921 | 2307 | 4096 | 1691 | 259 | 151 | 51 | 269 | 214 | 9959 |

Table 16. Total estimated abundance-at-age numbers (000's) of haddock in unit areas 5Zjm from the fall USA survey. Conversion factors to adjust for changes in door type and survey vessel were applied.

| Year | Age Groups | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ | Total |
| 1963 | 106461 | 49869 | 14797 | 5050 | 7581 | 6172 | 2301 | 599 | 273 | 193101 |
| 1964 | 1177 | 114880 | 55741 | 6128 | 976 | 2435 | 502 | 280 | 167 | 182287 |
| 1965 | 259 | 1512 | 51521 | 8360 | 489 | 299 | 148 | 165 | 216 | 62970 |
| 1966 | 9324 | 751 | 1742 | 20324 | 3631 | 671 | 139 | 133 | 83 | 36797 |
| 1967 | 0 | 3998 | 73 | 328 | 1845 | 675 | 140 | 88 | 88 | 7234 |
| 1968 | 55 | 113 | 800 | 28 | 37 | 2223 | 547 | 177 | 313 | 4293 |
| 1969 | 384 | 0 | 0 | 519 | 63 | 30 | 753 | 458 | 115 | 2323 |
| 1970 | 0 | 6400 | 336 | 16 | 415 | 337 | 500 | 902 | 578 | 9483 |
| 1971 | 2626 | 0 | 788 | 97 | 0 | 265 | 27 | 73 | 594 | 4471 |
| 1972 | 4747 | 2396 | 0 | 232 | 0 | 0 | 53 | 0 | 276 | 7703 |
| 1973 | 1345 | 16797 | 1606 | 0 | 180 | 1 | 0 | 16 | 16 | 19961 |
| 1974 | 151 | 234 | 961 | 169 | 0 | 6 | 0 | 0 | 69 | 1589 |
| 1975 | 30365 | 664 | 192 | 1018 | 222 | 0 | 0 | 0 | 26 | 32487 |
| 1976 | 784 | 132622 | 456 | 25 | 484 | 71 | 0 | 17 | 36 | 134496 |
| 1977 | 47 | 238 | 26323 | 445 | 125 | 211 | 84 | 4 | 4 | 27480 |
| 1978 | 14642 | 547 | 530 | 7706 | 56 | 42 | 94 | 0 | 0 | 23617 |
| 1979 | 1573 | 21117 | 14 | 327 | 1461 | 44 | 12 | 0 | 0 | 24549 |
| 1980 | 3581 | 2817 | 5877 | 0 | 101 | 1085 | 109 | 26 | 4 | 13598 |
| 1981 | 616 | 4617 | 2585 | 2752 | 105 | 136 | 297 | 0 | 15 | 11123 |
| 1982 | 62 | 0 | 669 | 460 | 2576 | 159 | 91 | 469 | 42 | 4527 |
| 1983 | 3609 | 444 | 324 | 435 | 283 | 396 | 19 | 9 | 79 | 5598 |
| 1984 | 45 | 3849 | 781 | 221 | 210 | 43 | 254 | 0 | 47 | 5451 |
| 1985 | 12148 | 381 | 1646 | 199 | 70 | 68 | 46 | 30 | 21 | 14610 |
| 1986 | 30 | 7471 | 109 | 961 | 52 | 50 | 72 | 24 | 23 | 8793 |
| 1987 | 508 | 4 | 839 | 28 | 152 | 38 | 22 | 0 | 0 | 1592 |
| 1988 | 122 | 3983 | 206 | 2326 | 155 | 400 | 142 | 140 | 38 | 7513 |
| 1989 | 167 | 83 | 2645 | 112 | 509 | 68 | 73 | 0 | 0 | 3656 |
| 1990 | 1217 | 1036 | 24 | 1474 | 90 | 172 | 21 | 5 | 0 | 4040 |
| 1991 | 705 | 331 | 274 | 68 | 266 | 25 | 10 | 0 | 0 | 1679 |
| 1992 | 3484 | 1052 | 172 | 110 | 0 | 95 | 0 | 18 | 18 | 4948 |
| 1993 | 677 | 6666 | 3601 | 585 | 0 | 87 | 96 | 30 | 0 | 11742 |
| 1994 | 625 | 782 | 927 | 419 | 96 | 32 | 0 | 24 | 0 | 2905 |
| 1995 | 892 | 1465 | 6165 | 3484 | 547 | 30 | 0 | 0 | 53 | 12637 |

Table 17. Statistical properties of estimates for population abundance and survey calibration constants for haddock in unit areas 5Zjm.

| Age | Estimate | Standard Error | Relative Error | Bias | Relative Bias |
|---|---|---|---|---|---|
| | | Population Abundance | | | |
| 1 | 7614 | 5302 | 0.70 | 1876 | 0.25 |
| 2 | 4915 | 2165 | 0.44 | 494 | 0.10 |
| 3 | 6375 | 2234 | 0.35 | 411 | 0.06 |
| 4 | 9098 | 2843 | 0.31 | 453 | 0.05 |
| 5 | 2202 | 740 | 0.34 | 123 | 0.06 |
| 6 | 360 | 128 | 0.35 | 21 | 0.06 |
| 7 | 207 | 83 | 0.40 | 15 | 0.07 |
| 8 | 16 | 10 | 0.62 | 3 | 0.17 |
| | | Survey Calibration Constants | | | |
| *Canadian Spring Survey* | | | | | |
| 1 | 0.164 | 0.050 | 0.303 | 0.007 | 0.040 |
| 2 | 0.403 | 0.119 | 0.295 | 0.015 | 0.038 |
| 3 | 0.836 | 0.245 | 0.293 | 0.032 | 0.038 |
| 4 | 0.677 | 0.198 | 0.292 | 0.026 | 0.039 |
| 5 | 0.817 | 0.240 | 0.294 | 0.033 | 0.041 |
| 6 | 0.578 | 0.171 | 0.295 | 0.025 | 0.043 |
| 7 | 0.826 | 0.255 | 0.308 | 0.044 | 0.053 |
| 8 | 0.740 | 0.227 | 0.307 | 0.041 | 0.055 |
| *USA Spring Survey* | | | | | |
| 1 | 0.145 | 0.028 | 0.193 | 0.002 | 0.016 |
| 2 | 0.366 | 0.069 | 0.188 | 0.006 | 0.016 |
| 3 | 0.455 | 0.087 | 0.191 | 0.007 | 0.016 |
| 4 | 0.511 | 0.098 | 0.191 | 0.008 | 0.017 |
| 5 | 0.586 | 0.110 | 0.188 | 0.010 | 0.017 |
| 6 | 0.456 | 0.089 | 0.196 | 0.008 | 0.019 |
| 7 | 0.706 | 0.140 | 0.198 | 0.015 | 0.021 |
| 8 | 0.645 | 0.129 | 0.200 | 0.015 | 0.023 |
| *USA Fall Survey* | | | | | |
| 1 | 0.139 | 0.026 | 0.187 | 0.002 | 0.015 |
| 2 | 0.309 | 0.060 | 0.193 | 0.005 | 0.016 |
| 3 | 0.233 | 0.044 | 0.188 | 0.004 | 0.016 |
| 4 | 0.207 | 0.039 | 0.188 | 0.003 | 0.016 |
| 5 | 0.166 | 0.033 | 0.200 | 0.003 | 0.020 |
| 6 | 0.155 | 0.029 | 0.189 | 0.003 | 0.017 |

Table 18. Beginning of year population abundance numbers (000's) for haddock in unit areas 5Zjm.

| Year | Age Group | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1+ | 2+ | 3+ |
| 1969 | 798 | 197 | 3515 | 871 | 856 | 6708 | 2325 | 239 | 0 | 15509 | 14711 | 14514 |
| 1970 | 3627 | 653 | 144 | 1582 | 479 | 403 | 2916 | 1172 | 117 | 11093 | 7466 | 6813 |
| 1971 | 192 | 2947 | 460 | 112 | 981 | 259 | 215 | 1367 | 631 | 7164 | 6972 | 4025 |
| 1972 | 5078 | 157 | 1323 | 145 | 63 | 579 | 67 | 30 | 454 | 7896 | 2818 | 2661 |
| 1973 | 10944 | 3904 | 128 | 726 | 52 | 32 | 396 | 18 | 13 | 16213 | 5269 | 1365 |
| 1974 | 2827 | 8045 | 1652 | 99 | 273 | 10 | 17 | 291 | 7 | 13221 | 10394 | 2349 |
| 1975 | 3416 | 2299 | 4718 | 1108 | 81 | 187 | 6 | 14 | 206 | 12035 | 8619 | 6320 |
| 1976 | 53925 | 2797 | 1717 | 2590 | 693 | 61 | 112 | 3 | 9 | 61907 | 7982 | 5185 |
| 1977 | 6299 | 44089 | 2156 | 1248 | 1386 | 459 | 50 | 77 | 3 | 55767 | 49468 | 5379 |
| 1978 | 4143 | 5158 | 29235 | 1707 | 861 | 861 | 230 | 41 | 50 | 42286 | 38143 | 32985 |
| 1979 | 40482 | 3391 | 3962 | 15122 | 1253 | 553 | 437 | 116 | 24 | 65340 | 24858 | 21467 |
| 1980 | 6175 | 33144 | 2757 | 3061 | 8429 | 734 | 289 | 184 | 60 | 54833 | 48658 | 15514 |
| 1981 | 4445 | 5054 | 18591 | 1941 | 2232 | 4755 | 429 | 122 | 104 | 37673 | 33228 | 28174 |
| 1982 | 2070 | 3639 | 3542 | 9314 | 1243 | 1302 | 2796 | 242 | 73 | 24221 | 22151 | 18512 |
| 1983 | 2423 | 1695 | 2337 | 1960 | 5105 | 841 | 726 | 1639 | 143 | 16869 | 14446 | 12751 |
| 1984 | 15454 | 1984 | 1203 | 1390 | 1145 | 2698 | 490 | 497 | 971 | 25832 | 10378 | 8394 |
| 1985 | 1543 | 12653 | 1553 | 758 | 826 | 707 | 1259 | 226 | 264 | 19789 | 18246 | 5593 |
| 1986 | 13301 | 1263 | 8502 | 935 | 463 | 506 | 468 | 698 | 137 | 26273 | 12972 | 11709 |
| 1987 | 1243 | 10885 | 1000 | 4666 | 610 | 252 | 304 | 277 | 416 | 19653 | 18410 | 7525 |
| 1988 | 15594 | 1018 | 7121 | 705 | 2462 | 413 | 156 | 176 | 166 | 27811 | 12217 | 11199 |
| 1989 | 780 | 12764 | 787 | 3905 | 468 | 1230 | 240 | 95 | 103 | 20372 | 19592 | 6828 |
| 1990 | 2512 | 639 | 9410 | 574 | 2536 | 267 | 719 | 169 | 59 | 16885 | 14373 | 13734 |
| 1991 | 2230 | 2055 | 517 | 6565 | 357 | 1410 | 157 | 442 | 100 | 13833 | 11603 | 9548 |
| 1992 | 7031 | 1821 | 1286 | 343 | 3544 | 213 | 805 | 64 | 231 | 15338 | 8307 | 6486 |
| 1993 | 16914 | 5751 | 1283 | 774 | 167 | 1609 | 95 | 377 | 30 | 27000 | 10086 | 4335 |
| 1994 | 8976 | 13842 | 4486 | 742 | 383 | 60 | 748 | 47 | 172 | 29456 | 20480 | 6638 |
| 1995 | 5400 | 7349 | 11137 | 3008 | 475 | 265 | 18 | 502 | 26 | 28180 | 22780 | 15431 |
| 1996 | 5738 | 4420 | 5965 | 8645 | 2079 | 339 | 193 | 13 | 363 | 27755 | 22017 | 17597 |

Table 19. Fishing mortality rate for haddock in unit areas 5Zjm.

| Year | Age Group | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 4+ |
| 1969 | 0.000 | 0.111 | 0.598 | 0.399 | 0.554 | 0.633 | 0.485 | 0.518 | 0.571 |
| 1970 | 0.008 | 0.151 | 0.058 | 0.278 | 0.415 | 0.426 | 0.557 | 0.419 | 0.440 |
| 1971 | 0.000 | 0.601 | 0.957 | 0.374 | 0.327 | 1.150 | 1.762 | 0.903 | 0.700 |
| 1972 | 0.063 | 0.006 | 0.400 | 0.824 | 0.475 | 0.180 | 1.132 | 0.653 | 0.349 |
| 1973 | 0.108 | 0.660 | 0.058 | 0.778 | 1.437 | 0.411 | 0.109 | 0.684 | 0.515 |
| 1974 | 0.007 | 0.334 | 0.200 | 0.000 | 0.177 | 0.394 | 0.003 | 0.143 | 0.134 |
| 1975 | 0.000 | 0.092 | 0.400 | 0.268 | 0.088 | 0.312 | 0.312 | 0.245 | 0.263 |
| 1976 | 0.001 | 0.060 | 0.119 | 0.425 | 0.213 | 0.000 | 0.176 | 0.000 | 0.361 |
| 1977 | 0.000 | 0.211 | 0.034 | 0.171 | 0.277 | 0.491 | 0.000 | 0.235 | 0.255 |
| 1978 | 0.000 | 0.064 | 0.459 | 0.109 | 0.244 | 0.478 | 0.484 | 0.329 | 0.240 |
| 1979 | 0.000 | 0.007 | 0.058 | 0.384 | 0.335 | 0.447 | 0.666 | 0.458 | 0.389 |
| 1980 | 0.000 | 0.378 | 0.151 | 0.116 | 0.373 | 0.337 | 0.661 | 0.372 | 0.308 |
| 1981 | 0.000 | 0.156 | 0.491 | 0.245 | 0.339 | 0.331 | 0.371 | 0.321 | 0.316 |
| 1982 | 0.000 | 0.243 | 0.392 | 0.401 | 0.191 | 0.384 | 0.334 | 0.328 | 0.367 |
| 1983 | 0.000 | 0.143 | 0.319 | 0.338 | 0.438 | 0.341 | 0.178 | 0.323 | 0.371 |
| 1984 | 0.000 | 0.045 | 0.262 | 0.321 | 0.282 | 0.562 | 0.575 | 0.435 | 0.440 |
| 1985 | 0.000 | 0.198 | 0.307 | 0.294 | 0.290 | 0.213 | 0.390 | 0.297 | 0.308 |
| 1986 | 0.000 | 0.033 | 0.400 | 0.228 | 0.409 | 0.309 | 0.323 | 0.317 | 0.301 |
| 1987 | 0.000 | 0.224 | 0.150 | 0.439 | 0.191 | 0.279 | 0.349 | 0.315 | 0.394 |
| 1988 | 0.000 | 0.057 | 0.401 | 0.208 | 0.494 | 0.342 | 0.295 | 0.335 | 0.405 |
| 1989 | 0.000 | 0.105 | 0.115 | 0.232 | 0.361 | 0.337 | 0.151 | 0.270 | 0.259 |
| 1990 | 0.001 | 0.012 | 0.160 | 0.275 | 0.387 | 0.330 | 0.287 | 0.320 | 0.348 |
| 1991 | 0.003 | 0.269 | 0.210 | 0.416 | 0.317 | 0.361 | 0.695 | 0.447 | 0.409 |
| 1992 | 0.001 | 0.150 | 0.308 | 0.521 | 0.590 | 0.611 | 0.558 | 0.569 | 0.580 |
| 1993 | 0.000 | 0.048 | 0.347 | 0.503 | 0.816 | 0.565 | 0.497 | 0.586 | 0.561 |
| 1994 | 0.000 | 0.017 | 0.199 | 0.247 | 0.168 | 0.987 | 0.199 | 0.378 | 0.231 |
| 1995 | 0.000 | 0.009 | 0.053 | 0.170 | 0.137 | 0.118 | 0.145 | 0.126 | 0.157 |

Table 20. Average weight at age from the Canadian spring survey.

| Year | Age Group | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1986 | 0.135 | 0.452 | 0.975 | 1.444 | 3.039 | 2.843 | 3.598 | 3.373 |
| 1987 | 0.150 | 0.500 | 0.716 | 1.673 | 2.011 | 2.548 | 3.150 | 3.147 |
| 1988 | 0.097 | 0.464 | 0.932 | 1.795 | 1.816 | 1.917 | 2.720 | 3.269 |
| 1989 | 0.062 | 0.474 | 0.650 | 1.392 | 1.994 | 2.528 | 2.155 | 2.820 |
| 1990 | 0.149 | 0.527 | 0.925 | 1.184 | 1.863 | 2.072 | 2.508 | 2.819 |
| 1991 | 0.120 | 0.689 | 0.801 | 1.510 | 1.686 | 2.427 | 2.103 | 3.125 |
| 1992 | 0.122 | 0.602 | 1.118 | 1.061 | 2.078 | 2.165 | 2.708 | 2.283 |
| 1993 | 0.122 | 0.481 | 1.228 | 1.803 | 1.270 | 2.332 | 2.340 | 2.738 |
| 1994 | 0.107 | 0.469 | 1.047 | 1.621 | 1.926 | 2.154 | 3.152 | 2.688 |
| 1995 | 0.086 | 0.493 | 0.963 | 1.556 | 2.224 | 2.447 | | 2.994 |
| 1996 | 0.134 | 0.475 | 0.878 | 1.327 | 1.904 | 2.501 | 2.969 | 3.190 |

Table 21. Beginning of year biomass for haddock in unit areas 5Zjm.

| Year | Age Group | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1+ | 2+ | 3+ |
| 1969 | 93 | 101 | 3270 | 1296 | 1697 | 15816 | 6364 | 705 | 0 | 29342 | 29249 | 29148 |
| 1970 | 423 | 334 | 134 | 2354 | 950 | 950 | 7982 | 3457 | 398 | 16982 | 16558 | 16224 |
| 1971 | 22 | 1507 | 428 | 167 | 1945 | 611 | 588 | 4032 | 2145 | 11446 | 11424 | 9916 |
| 1972 | 593 | 80 | 1231 | 216 | 125 | 1365 | 183 | 88 | 1544 | 5425 | 4832 | 4752 |
| 1973 | 1277 | 1997 | 119 | 1080 | 103 | 75 | 1084 | 53 | 44 | 5833 | 4556 | 2559 |
| 1974 | 330 | 4115 | 1537 | 147 | 541 | 24 | 47 | 858 | 24 | 7623 | 7293 | 3178 |
| 1975 | 399 | 1176 | 4389 | 1649 | 161 | 441 | 16 | 41 | 700 | 8972 | 8573 | 7397 |
| 1976 | 6295 | 1431 | 1597 | 3854 | 1374 | 144 | 307 | 9 | 31 | 15040 | 8745 | 7315 |
| 1977 | 735 | 22551 | 2006 | 1857 | 2748 | 1082 | 137 | 227 | 10 | 31354 | 30618 | 8067 |
| 1978 | 484 | 2638 | 27196 | 2540 | 1707 | 2030 | 630 | 121 | 170 | 37516 | 37032 | 34394 |
| 1979 | 4725 | 1734 | 3686 | 22500 | 2484 | 1304 | 1196 | 342 | 82 | 38054 | 33328 | 31594 |
| 1980 | 721 | 16953 | 2565 | 4554 | 16713 | 1731 | 791 | 543 | 204 | 44774 | 44053 | 27100 |
| 1981 | 519 | 2585 | 17295 | 2888 | 4425 | 11211 | 1174 | 360 | 354 | 40811 | 40292 | 37707 |
| 1982 | 242 | 1861 | 3295 | 13858 | 2465 | 3070 | 7653 | 714 | 248 | 33406 | 33164 | 31303 |
| 1983 | 283 | 867 | 2174 | 2916 | 10122 | 1983 | 1987 | 4834 | 486 | 25653 | 25370 | 24503 |
| 1984 | 1804 | 1015 | 1119 | 2068 | 2270 | 6361 | 1341 | 1466 | 3301 | 20746 | 18942 | 17927 |
| 1985 | 180 | 6472 | 1445 | 1128 | 1638 | 1667 | 3446 | 667 | 898 | 17540 | 17360 | 10888 |
| 1986 | 1791 | 570 | 8292 | 1351 | 1407 | 1439 | 1684 | 2354 | 466 | 19353 | 17562 | 16992 |
| 1987 | 187 | 5438 | 716 | 7805 | 1227 | 642 | 957 | 872 | 1414 | 19259 | 19072 | 13634 |
| 1988 | 1516 | 473 | 6634 | 1266 | 4471 | 792 | 424 | 575 | 564 | 16714 | 15199 | 14726 |
| 1989 | 48 | 6051 | 511 | 5436 | 933 | 3109 | 517 | 268 | 350 | 17225 | 17177 | 11125 |
| 1990 | 374 | 337 | 8703 | 680 | 4724 | 553 | 1803 | 476 | 201 | 17851 | 17477 | 17141 |
| 1991 | 269 | 1415 | 414 | 9916 | 602 | 3422 | 330 | 1381 | 340 | 18089 | 17820 | 16405 |
| 1992 | 860 | 1097 | 1438 | 364 | 7363 | 461 | 2180 | 146 | 785 | 14695 | 13835 | 12738 |
| 1993 | 2062 | 2767 | 1576 | 1396 | 212 | 3753 | 222 | 1032 | 102 | 13122 | 11060 | 8293 |
| 1994 | 957 | 6494 | 4698 | 1203 | 738 | 129 | 2358 | 126 | 585 | 17289 | 16331 | 9837 |
| 1995 | 465 | 3626 | 10724 | 4680 | 1056 | 649 | 49 | 1503 | 88 | 22839 | 22374 | 18748 |
| 1996 | 767 | 2100 | 5238 | 11475 | 3959 | 848 | 573 | 41 | 1234 | 26236 | 25469 | 23369 |

Table 22. Projection results at $F_{0.1}$ for haddock in unit areas 5Zjm.

| Year | Age Group | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1+ | 2+ | 3+ |
| *Population Numbers (000s)* | | | | | | | | | | | | |
| 1996 | 5738 | 4420 | 5965 | 8645 | 2079 | 339 | 193 | 13 | 363 | 27755 | 22017 | 17597 |
| 1997 | 10000 | 4698 | 3569 | 4245 | 5349 | 1286 | 210 | 119 | 8 | 29484 | 19484 | 14786 |
| *Fishing Mortality* | | | | | | | | | | | | |
| 1996 | 0.000 | 0.014 | 0.140 | 0.280 | 0.280 | 0.280 | 0.280 | 0.280 | | | | |
| *Weight at beginning of year for population (kg)* | | | | | | | | | | | | |
| 1997 | 0.11 | 0.48 | 0.96 | 1.50 | 2.02 | 2.37 | 2.94 | 2.96 | 3.40 | | | |
| *Projected Population Biomass (t)* | | | | | | | | | | | | |
| 1997 | 1100 | 2255 | 3426 | 6368 | 10806 | 3048 | 617 | 353 | 27 | 28000 | 26900 | 24645 |
| *Projected Catch Numbers (000s)* | | | | | | | | | | | | |
| 1996 | 0 | 56 | 708 | 1922 | 462 | 75 | 43 | 3 | | | | |
| *Average weight for catch (kg)* | | | | | | | | | | | | |
| 1996 | 0.62 | 1.11 | 1.63 | 2.15 | 2.41 | 2.60 | 2.71 | 3.12 | | | | |
| *Projected Yield (t)* | | | | | | | | | | | | |
| 1996 | 0 | 62 | 1154 | 4133 | 1114 | 196 | 116 | 9 | | 6784 | | |

Table 23. For the derivation of the maximum carry-over, it was assumed that the age composition of the uncaught haddock in 1995 was the same as the age composition of those that were caught.

| Age | Weight | Caught in 1995 | | Left in 1995 | | Carry-over in 1996 | |
|---|---|---|---|---|---|---|---|
| | | Number | Biomass (kg) | Number | Biomass (kg) | Number | Biomass (kg) |
| 1 | 0.797 | 1287 | 1025 | 272 | 217 | 0 | 0 |
| 2 | 1.047 | 56544 | 59193 | 11944 | 12504 | 223 | 233 |
| 3 | 1.513 | 502036 | 759741 | 106050 | 160488 | 9779 | 14799 |
| 4 | 2.038 | 407038 | 829367 | 85983 | 175196 | 86827 | 176915 |
| 5 | 2.554 | 52090 | 133056 | 11003 | 28107 | 70397 | 179818 |
| 6 | 2.761 | 24511 | 67668 | 5178 | 14294 | 9009 | 24871 |
| 7 | 2.916 | 2266 | 6608 | 479 | 1396 | 4239 | 12363 |
| 8 | 3.011 | 50882 | 153204 | 10748 | 32363 | 392 | 1180 |
| 9 | 3.033 | 5322 | 16138 | 1124 | 3409 | 8800 | 26687 |
| 10 | 3.613 | 5718 | 20661 | 1208 | 4364 | 920 | 3325 |
| 11 | 3.907 | 1481 | 5785 | 313 | 1222 | 989 | 3864 |
| 12 | 4.233 | 2712 | 11479 | 573 | 2425 | 256 | 1084 |
| Total | | | 2063925 | | 435984 | | 445139 |

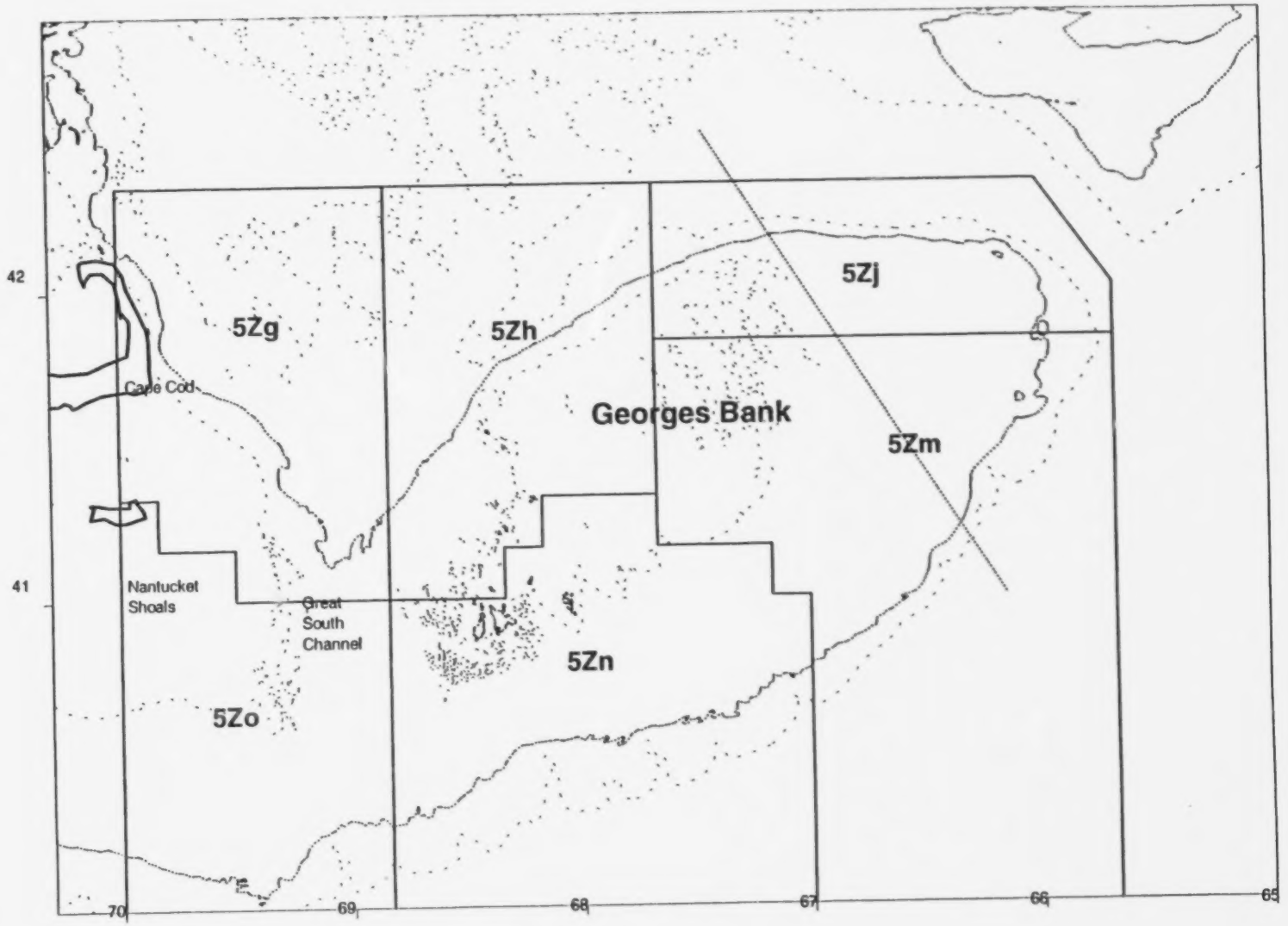


Fig. 1. Canadian fisheries statistical unit areas in NAFO Subdivision 5Ze.

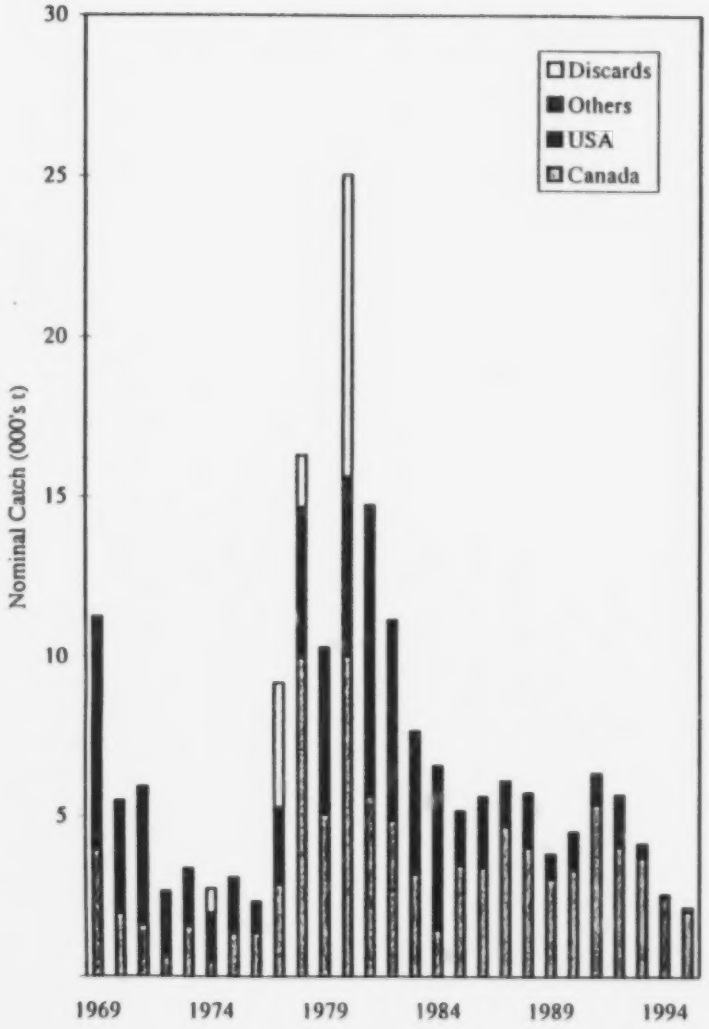


Fig. 2. Nominal catch of haddock in unit areas 5Zjm.

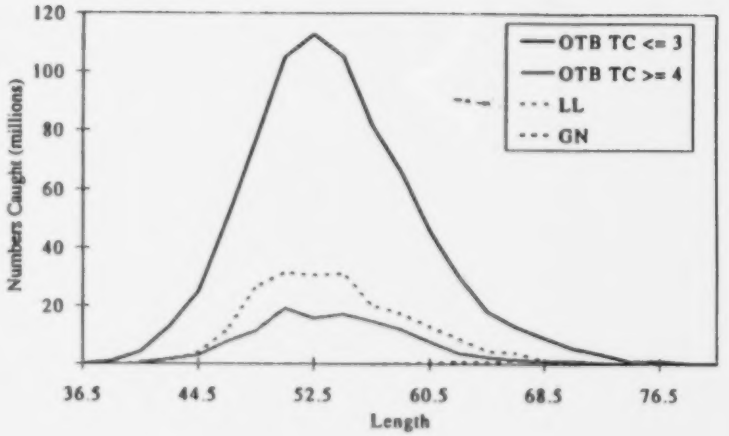


Fig. 3. Length composition of haddock catch in 1994 by the principle gear sectors for the Canadian fishery in unit areas 5Zjm.

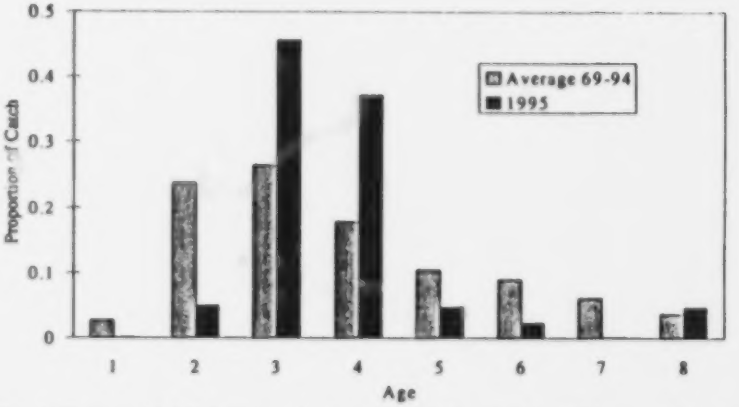


Fig. 4. Commercial fishery catch proportioned by age for 1995 compared to the average for 1969-94.

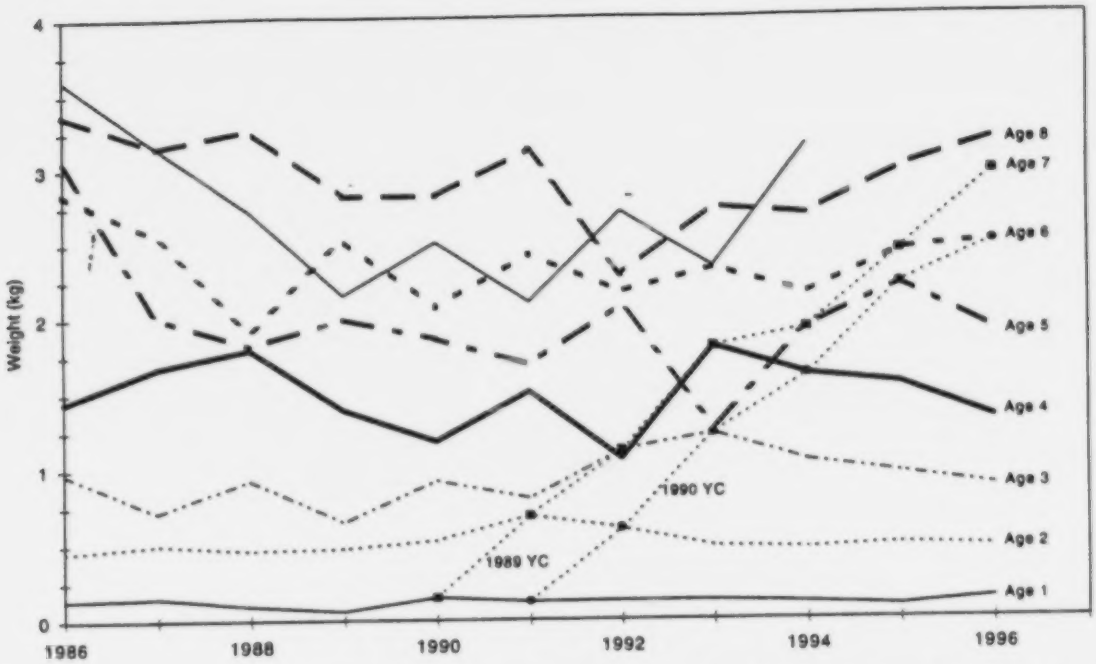


Fig. 5. Average weights at age from the Canadian spring survey. The 1989 and 1990 year-classes weights at age are generally larger than the adjacent weights in this series, especially for ages 2, 3, 4 and 5.

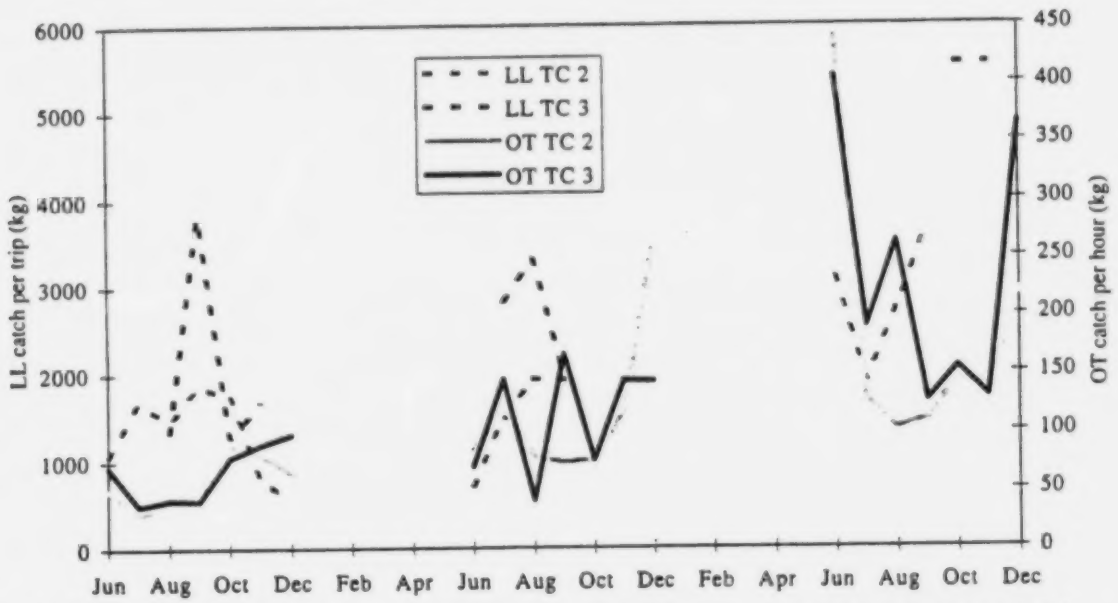
LL TC 2
LL TC 3
OT TC 2
OT TC 3
LL catch per trip (kg)
OT catch per hour (kg)
Jun Aug Oct Dec Feb Apr Jun Aug Oct Dec Feb Apr Jun Aug Oct Dec

Fig. 6. Indices of catch per hour for otter trawls and catch per trip for longlines from the Canadian commercial fisheries.

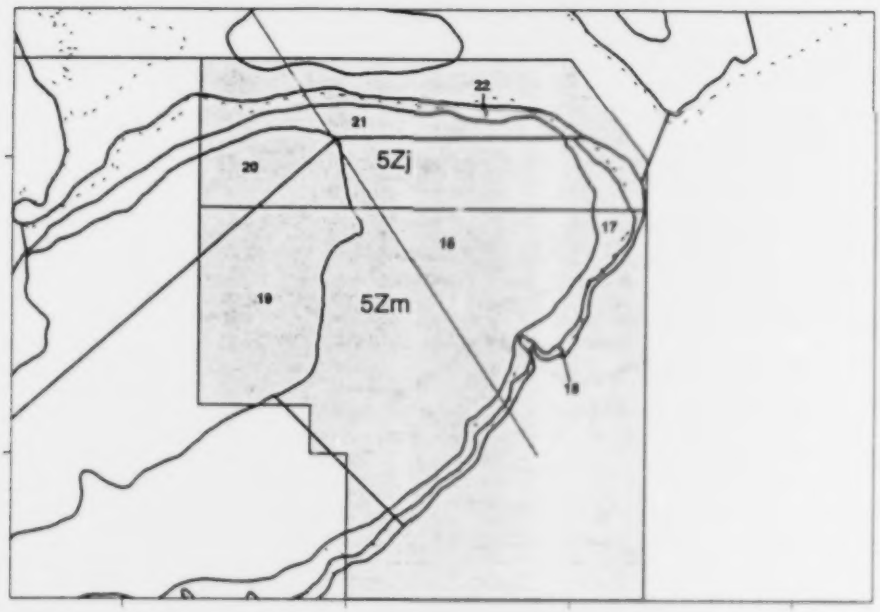


Fig. 7. Stratification scheme used for USA surveys.

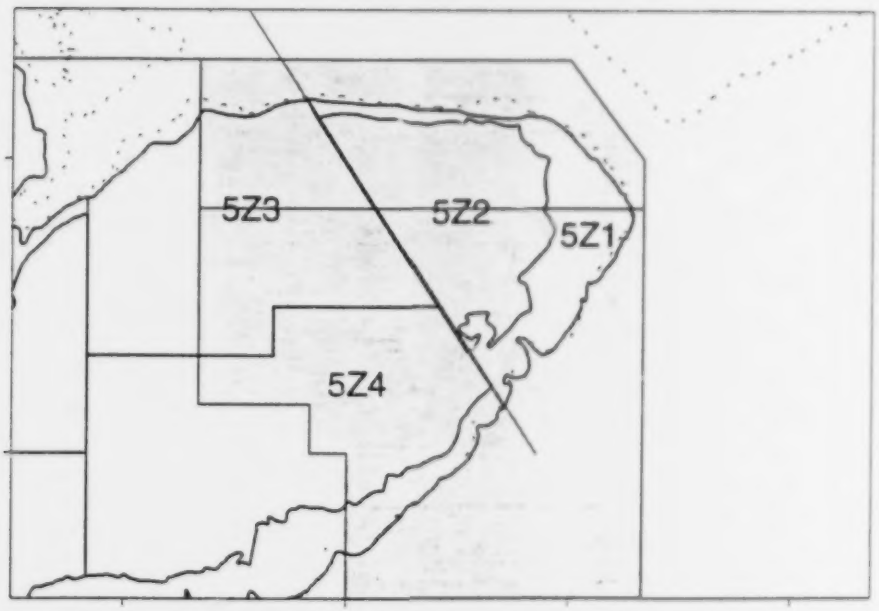


Fig. 8. Stratification scheme used for the Canadian survey.

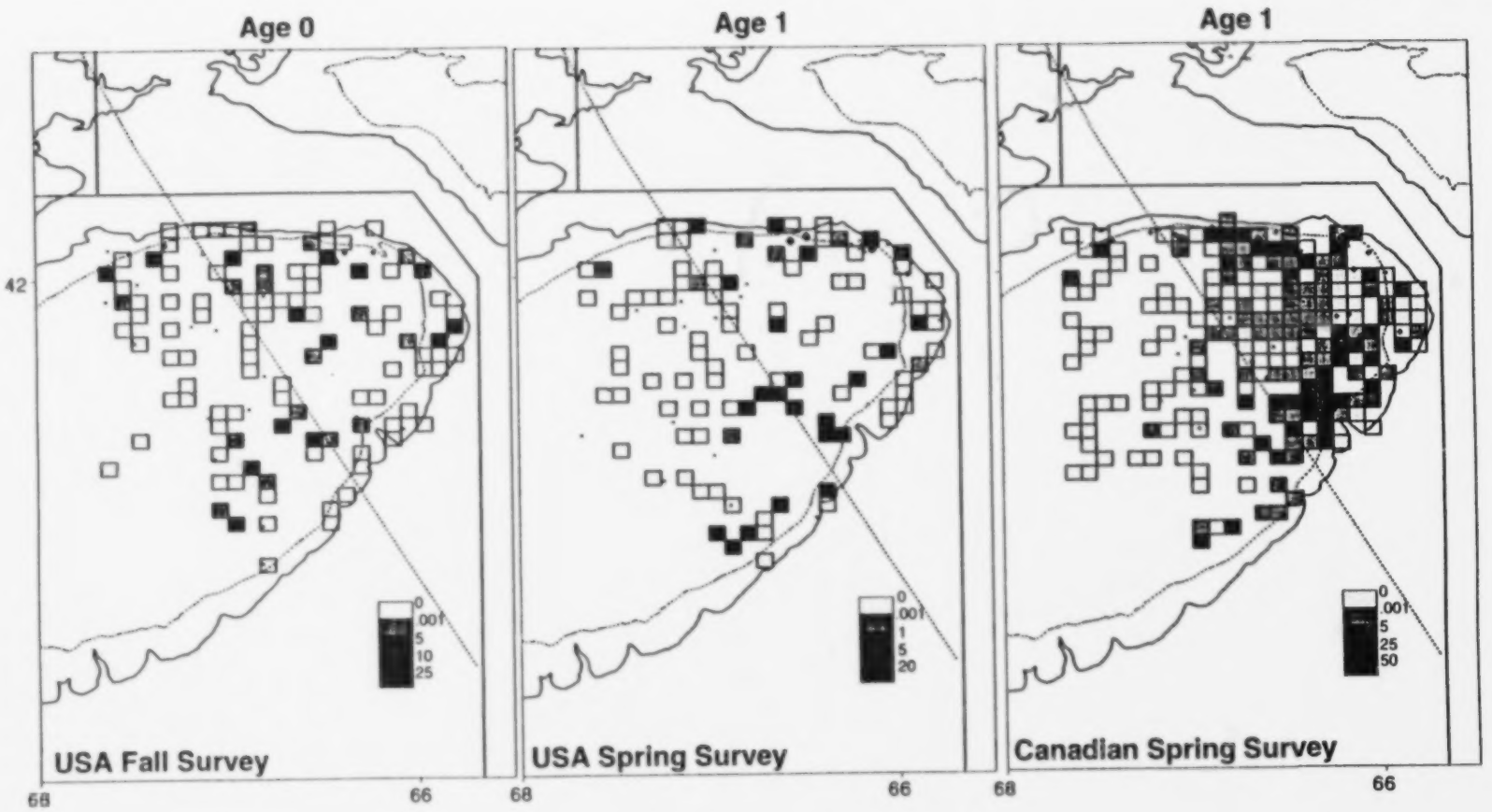


Fig. 9. Distribution of 5Zjm haddock at age 0 as observed from the USA fall survey and at age 1 from the USA and Canadian spring surveys. The squares are shaded relative to the average catch for 1990 to 1994 for the USA surveys and for 1990 to 1995 for the Canadian survey. The expanding symbols represent the 1995 USA survey catches and the 1996 Canadian survey catches. During the fall, age 0 haddock are distributed throughout the survey area but by the next spring, at age 1, they are concentrated on the Canadian side although aggregations occur along the southern flank of the bank in USA territory.

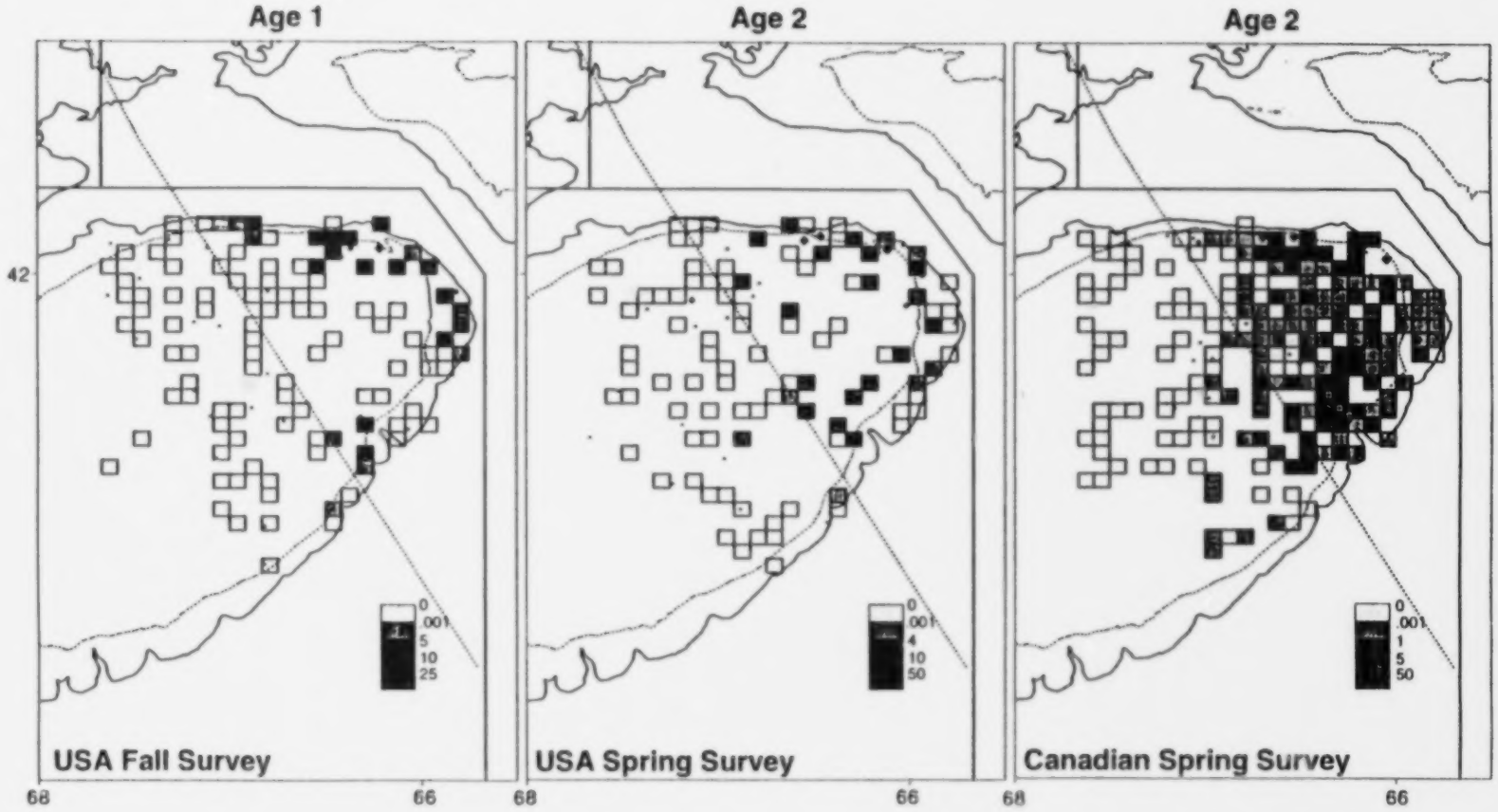


Fig. 10. Distribution of 5Zjm haddock at age 1 as observed from the USA fall survey and at age 2 from the USA and Canadian spring surveys. The squares are shaded relative to the average catch for 1990 to 1994 for the USA surveys and for 1990 to 1995 for the Canadian survey. The expanding symbols represent the 1995 USA survey catches and the 1996 Canadian survey catches. During the fall, age 1 haddock are concentrated along the edge of the bank, especially the north-eastern edge. In the spring, at age 2, they are concentrated on the Canadian side although aggregations may occur along the southern flank of the bank in USA territory as observed from the Canadian survey.

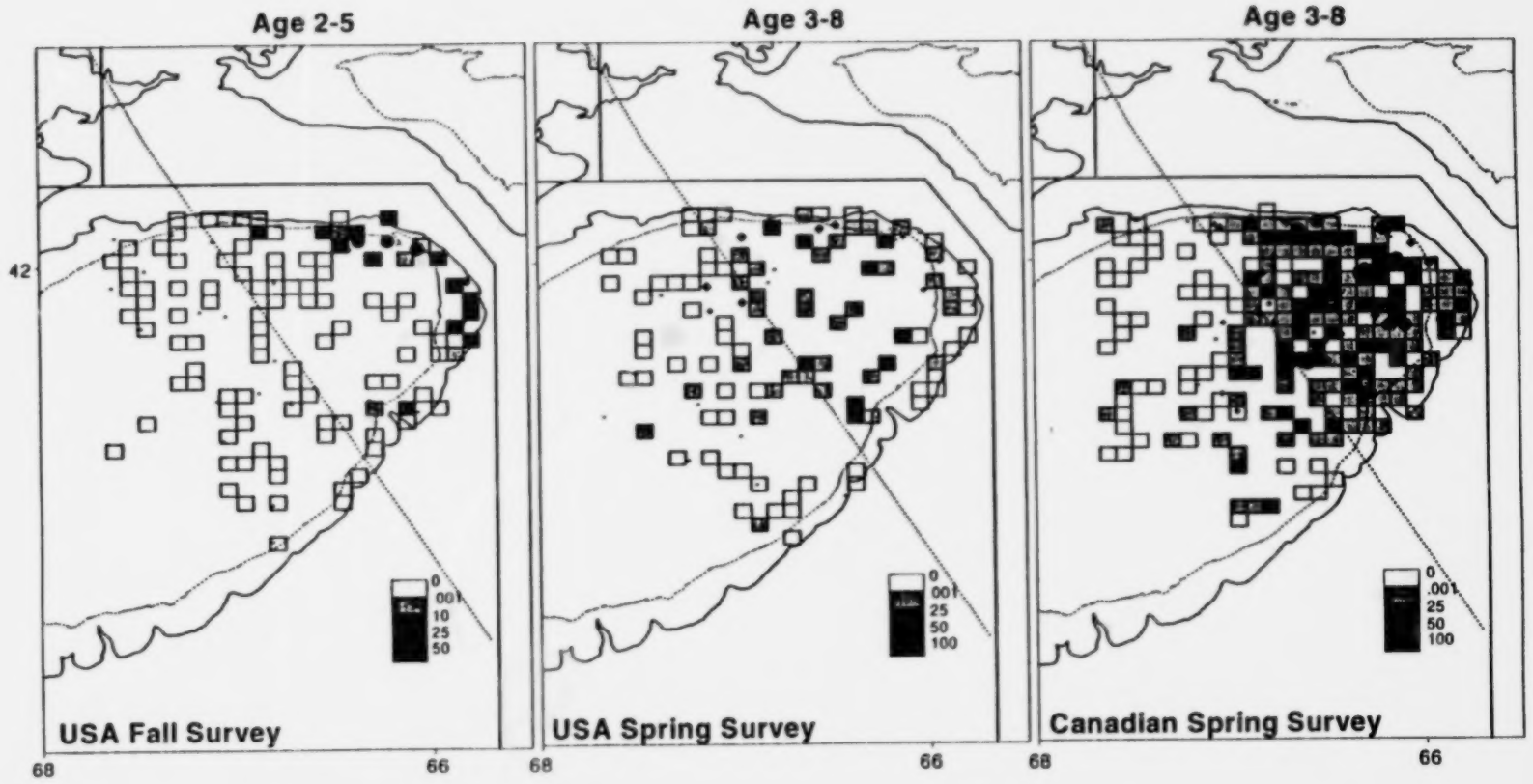


Fig. 11. Distribution of 5Zjm haddock at ages 2 to 5 as observed from the USA fall survey and at ages 3 to 8 from the USA and Canadian spring surveys. The squares are shaded relative to the average catch for 1990 to 1994 for the USA surveys and for 1990 to 1995 for the Canadian survey. The expanding symbols represent the 1995 USA survey catches and the 1996 Canadian survey catches. During the fall, age 2 to 5 haddock are concentrated along the edge of the bank, especially the north-eastern edge, in Canadian territory. In the spring, at age 3 to 8, movement across the Canada/USA boundary line into USA territory has occurred but the Canadian side still maintains the highest concentrations.

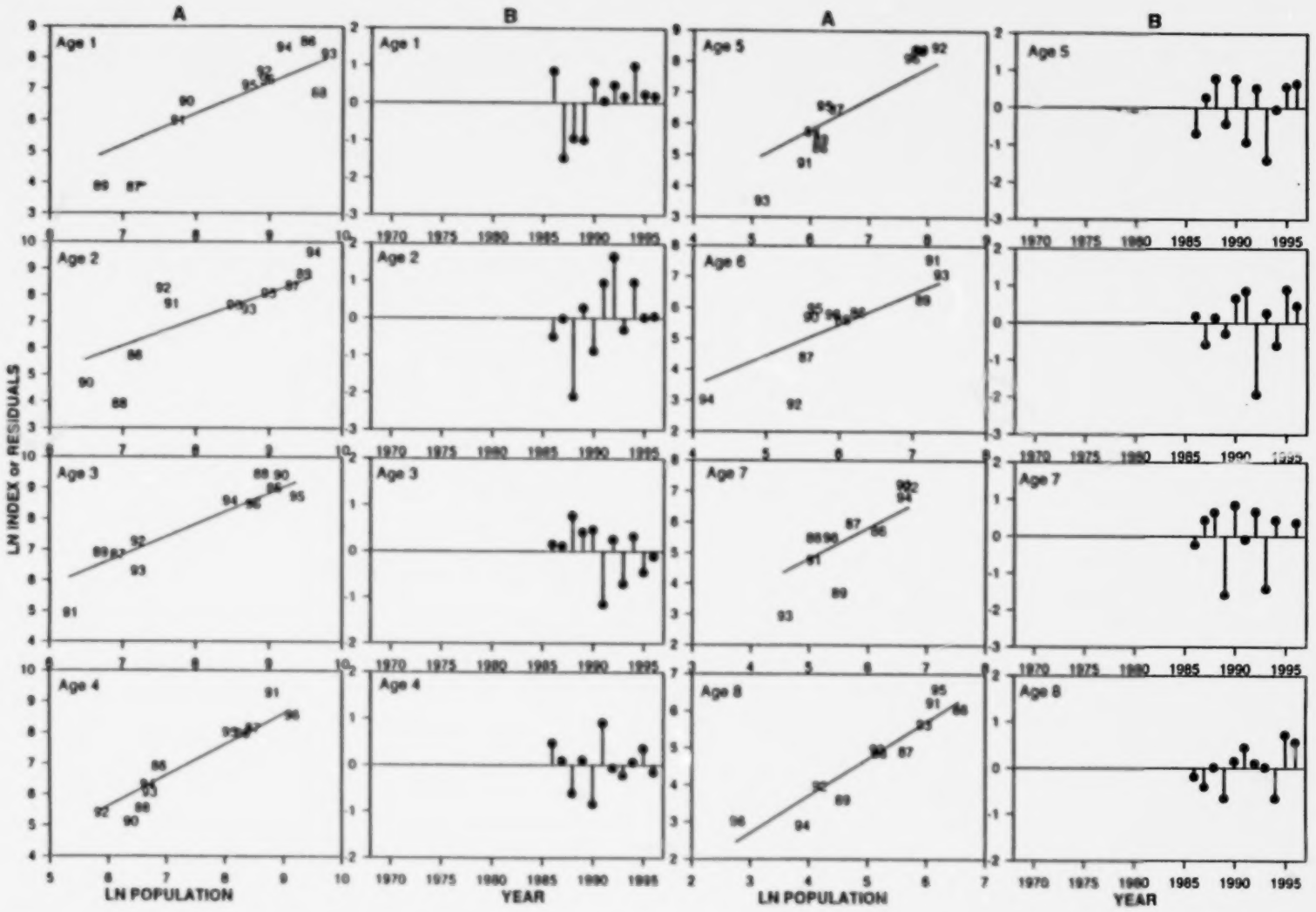


Fig. 12a. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers, and B) residuals plotted against year for haddock in unit areas 5Zj and 5Zm for the Canadian spring survey.

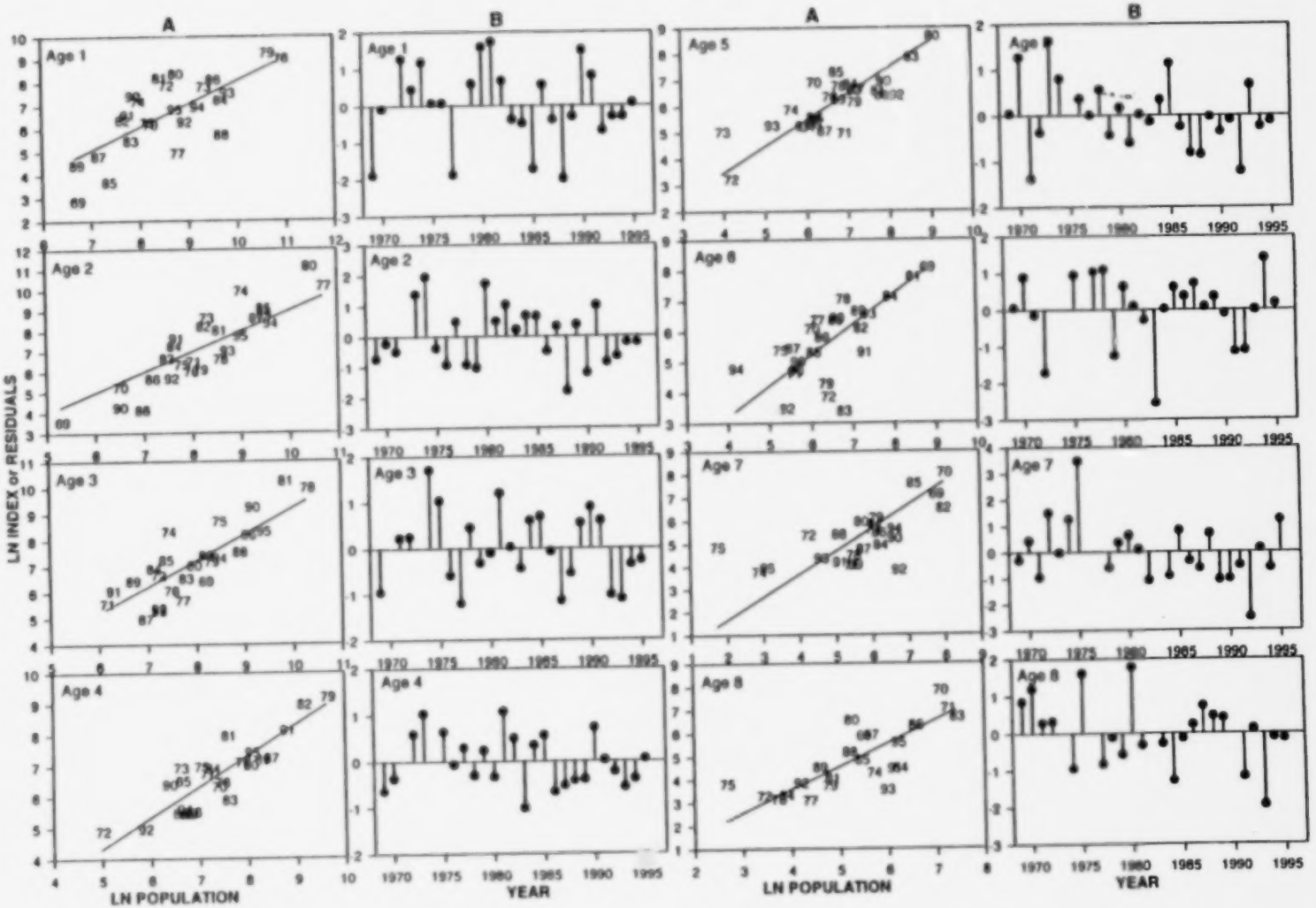


Fig. 12b. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers, and B) residuals plotted against year for haddock in unit areas 5Zj and 5Zm for the USA spring survey.

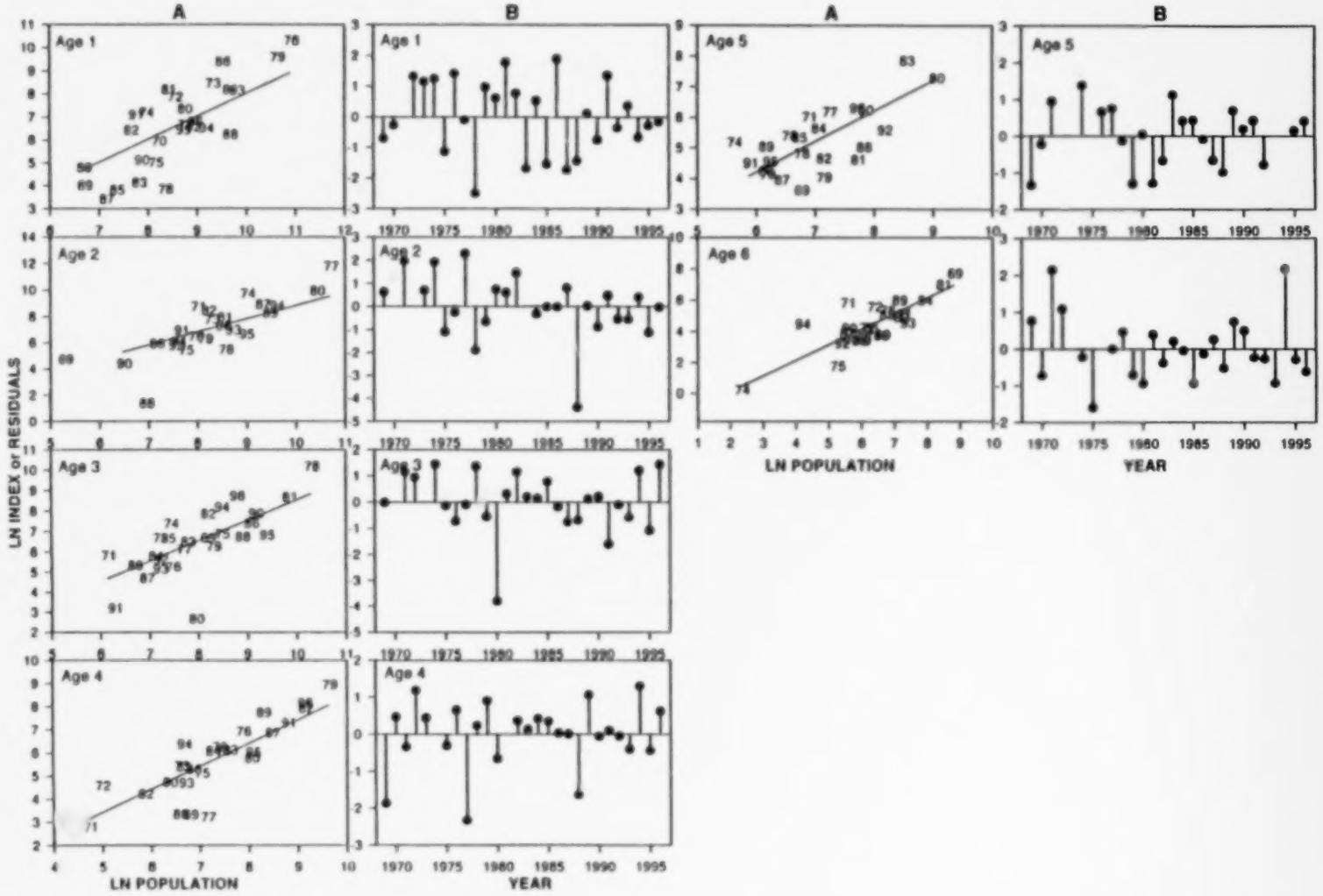


Fig. 12c. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers, and B) residuals plotted against year for haddock in unit areas 5Zj and 5Zm for the USA fall survey.

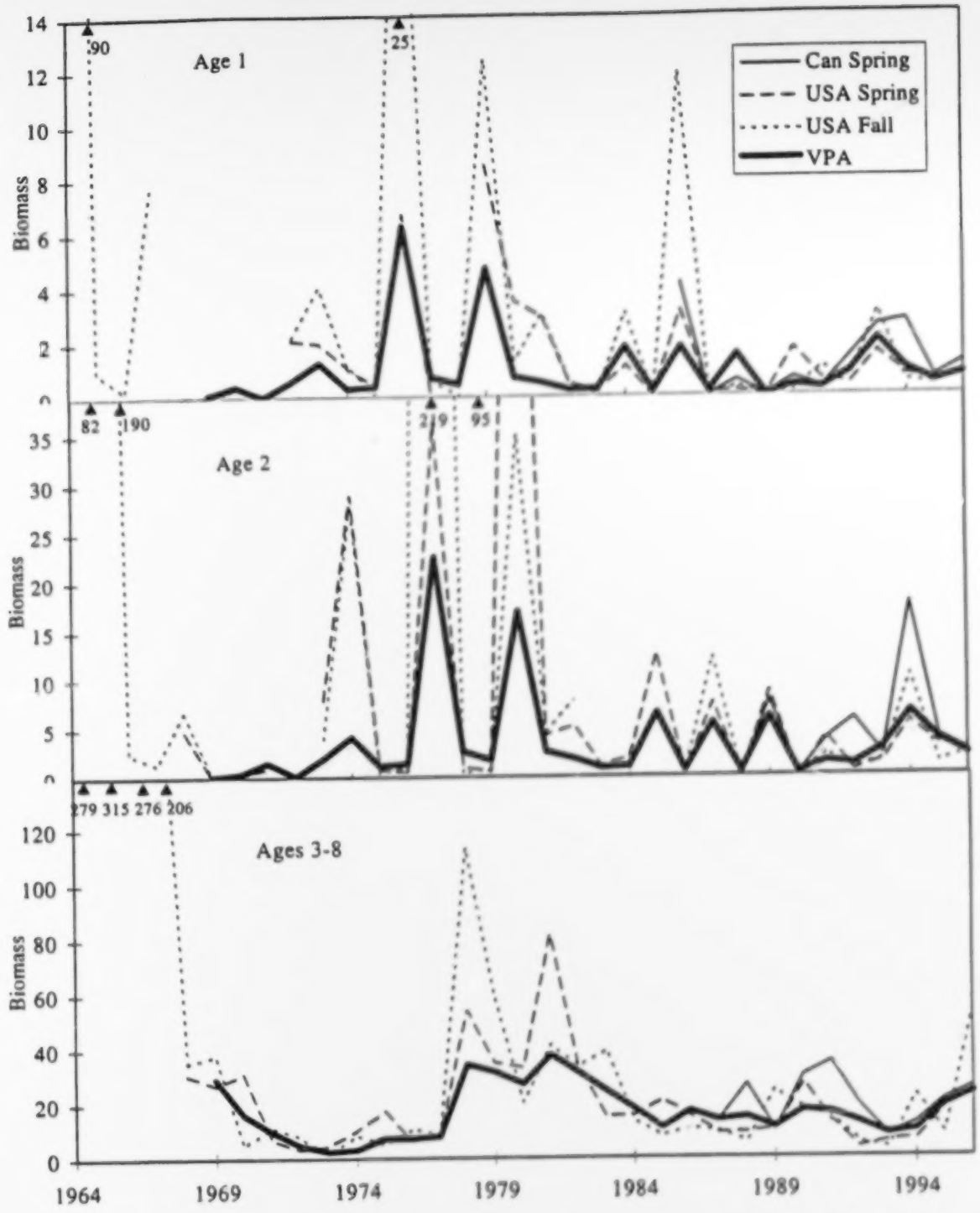


Fig. 13. Beginning of year biomass from sequential population analysis and research survey indices, adjusted by calibration constants, for haddock in unit areas 5Zjm. Fall survey values are compared to beginning of the subsequent year.

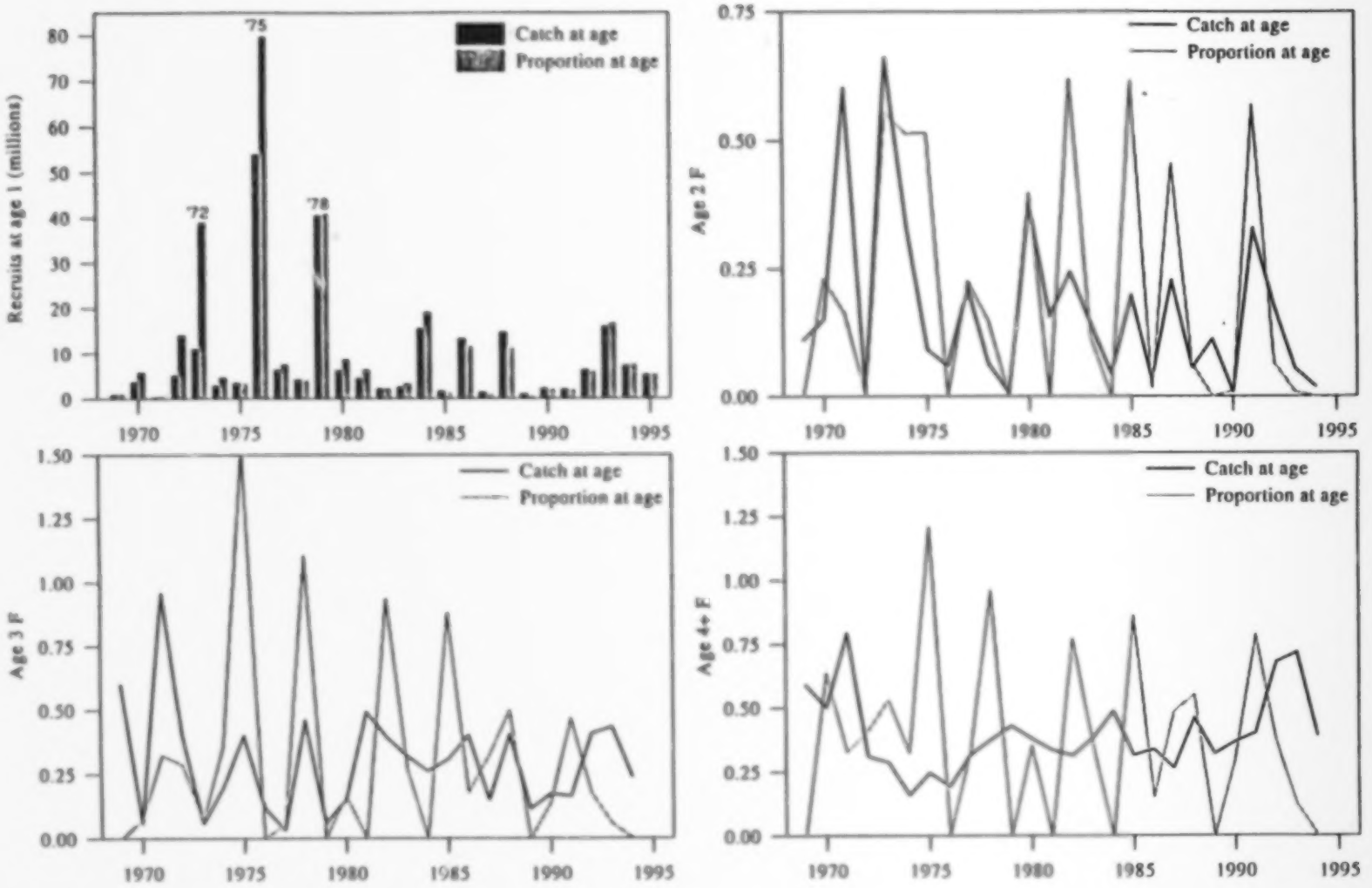


Fig. 14. Comparison of results from a traditional calibaration model to one using abundance indices and proportion caught at age. The relative year-class abundances were scaled to the 1994 age 1 abundance from the traditional calibration.

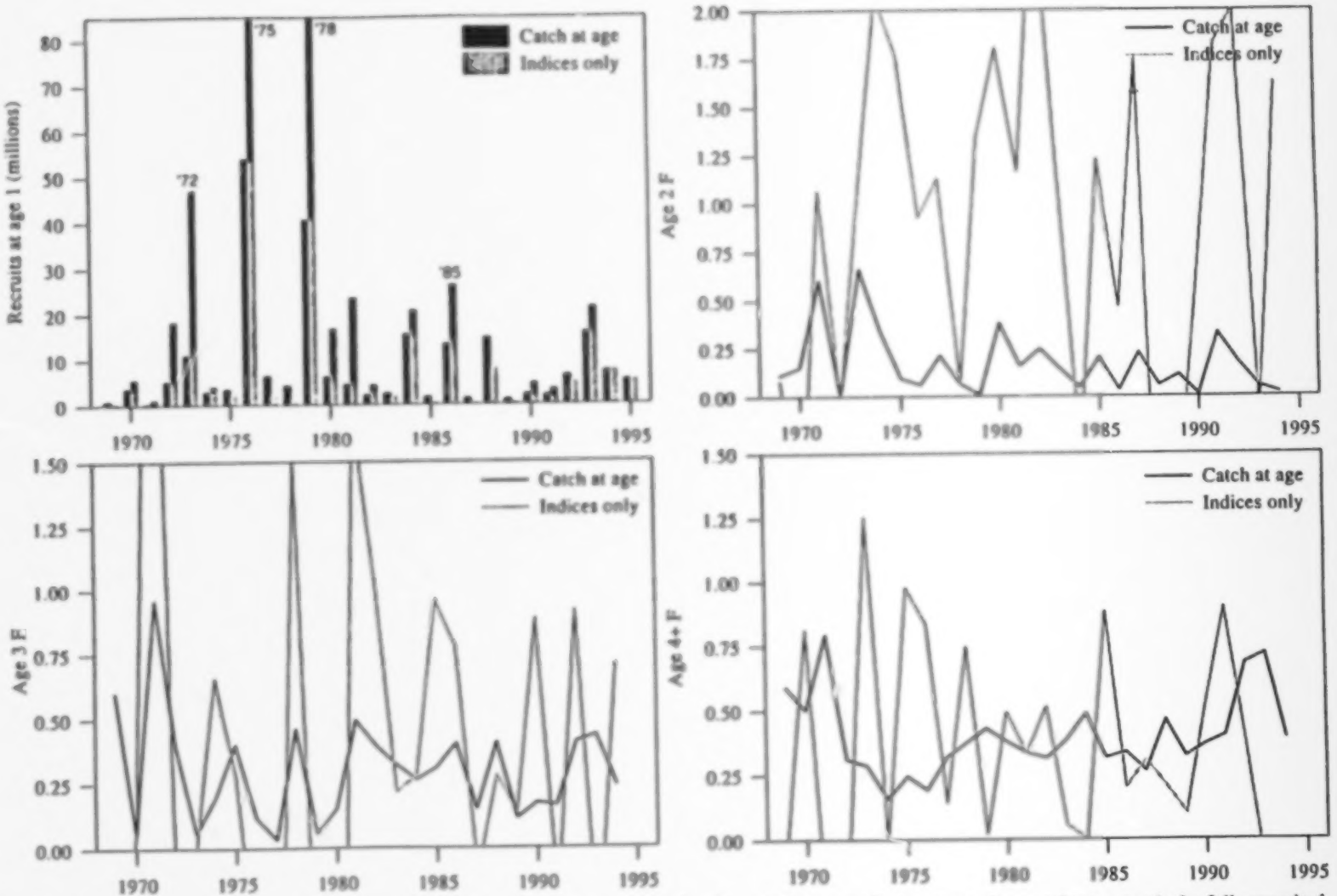


Fig. 15. Comparison of results from a traditional calibration model to one using abundance indices, employing proportion caught at age only for fully recruited ages to calculate oldest age abundance. The relative year-class abundances were scaled to the 1994 age 1 abundance from the traditional calibration.

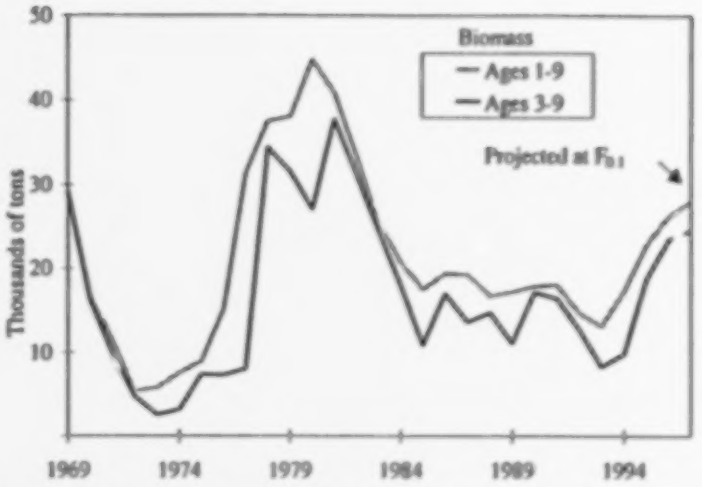


Fig. 16. Beginning of year biomass for haddock in unit areas 5Zjm.

Fig. 18. Exploitation rate for haddock ages 4 and older in unit areas 5Zjm.

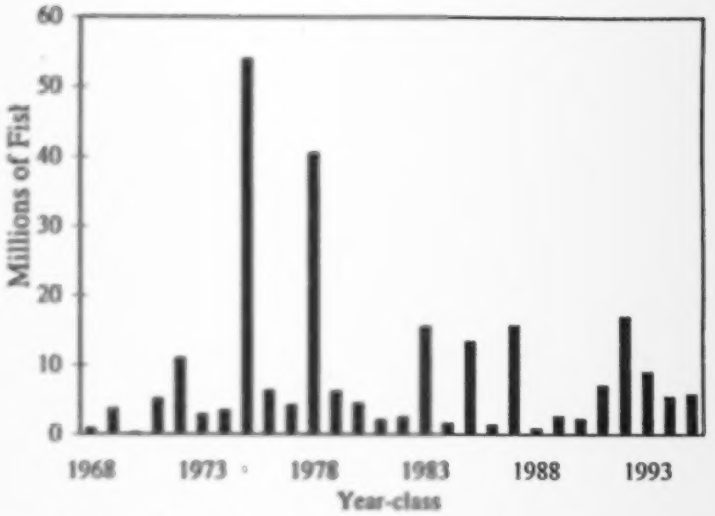


Fig. 17. Number of age 1 recruits for haddock in unit areas 5Zjm.

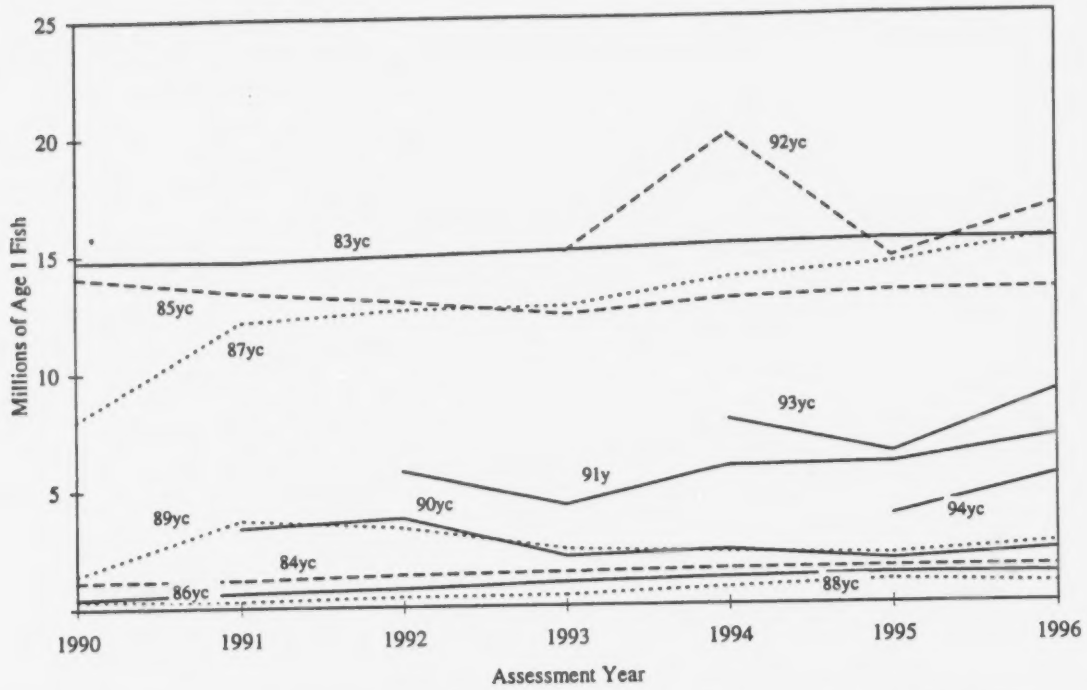


Fig. 19 . Successive estimates of year-class abundance as additional years of data were included in the assessment did not display any persistent trends.

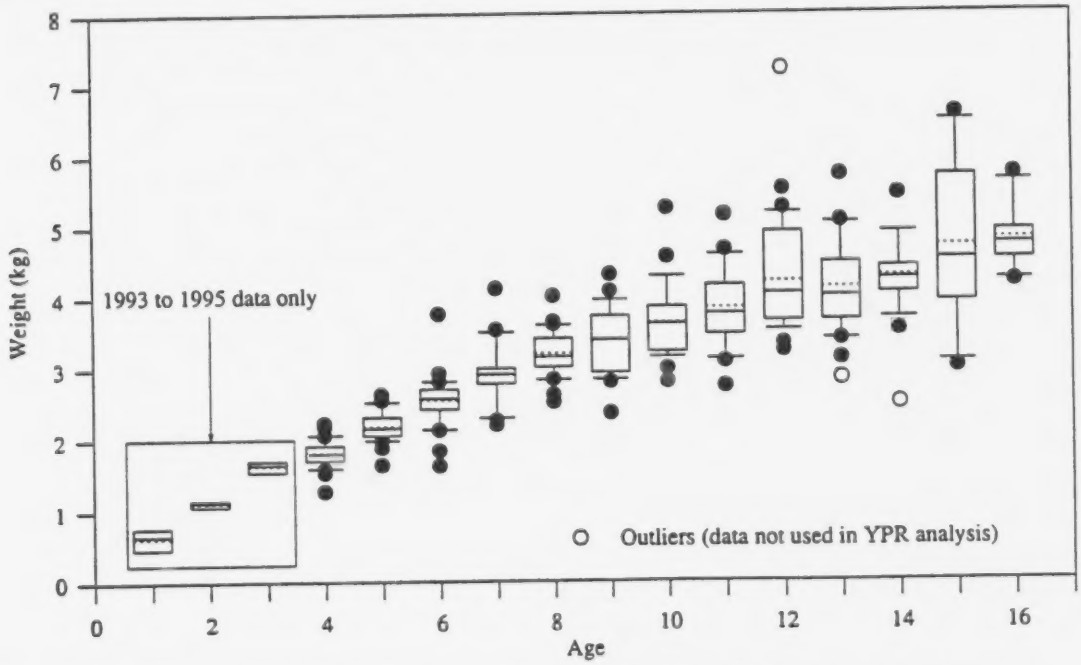


Fig. 20. Weights at age used in yield per recruit analysis. 1985-95 data was used for ages 4-16.The means, as indicated by the dotted lines, were used in the analysis. Three points were omitted as only 1 or 2 fish were aged.

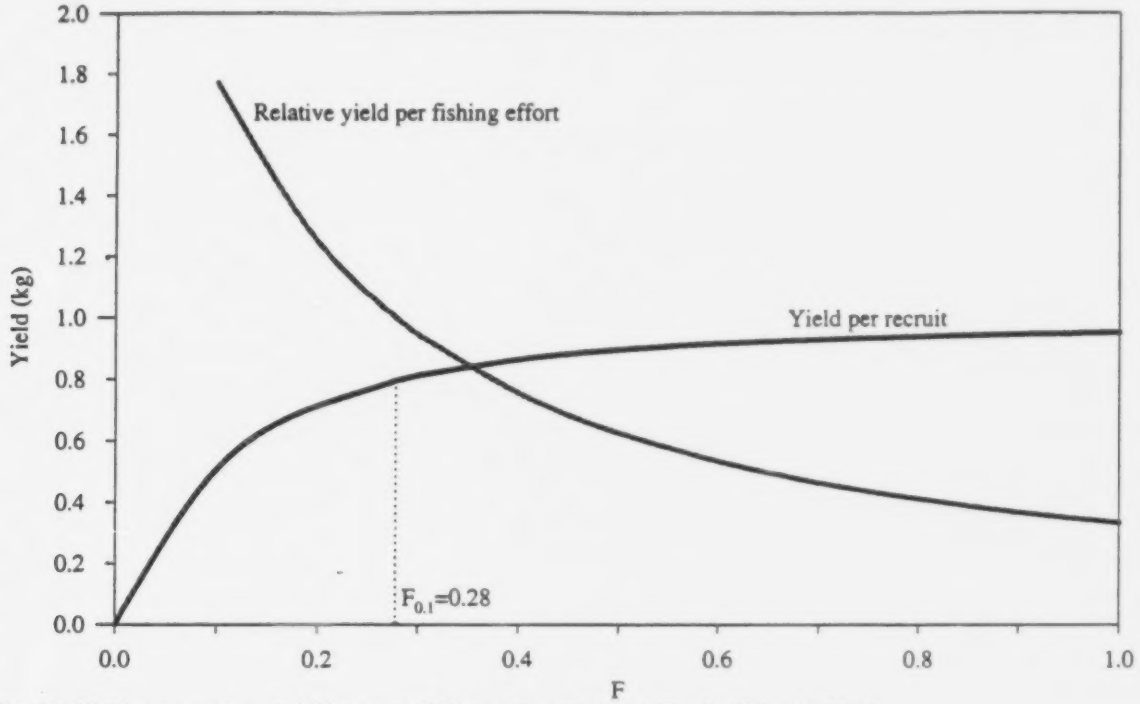


Fig. 21. Yield per recruit and yield per unit fishing effort relative to $F_{0.1}$ for 5Zj,m haddock.

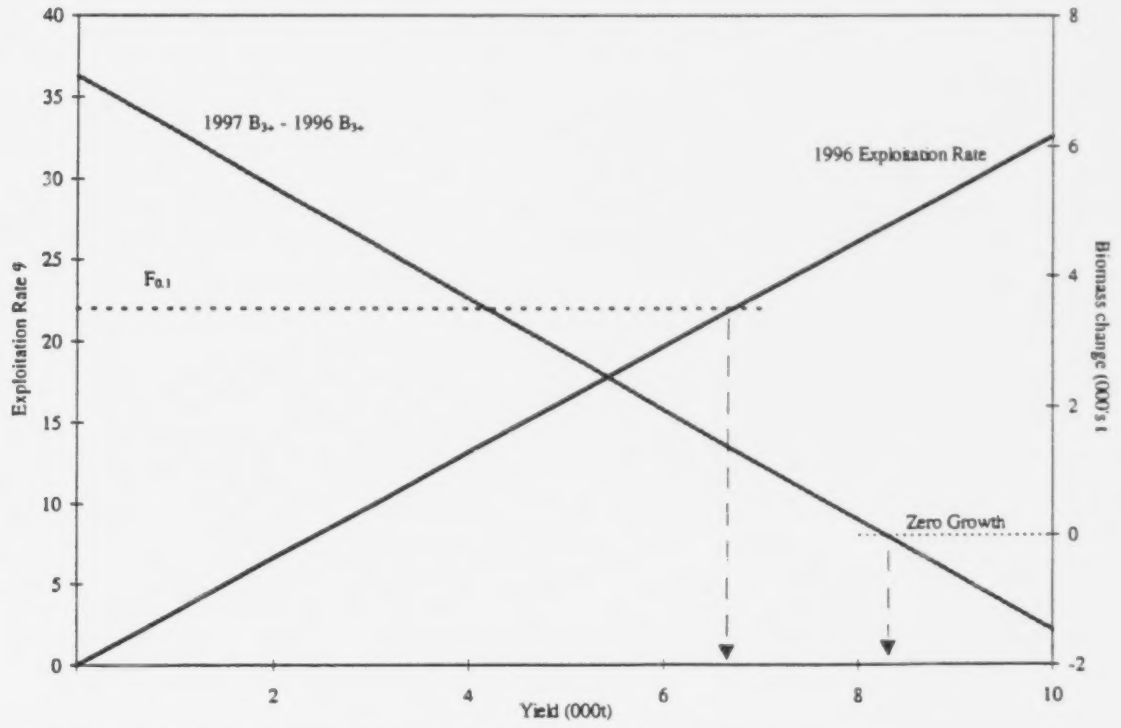


Fig. 22. Projected change in biomass from 1996 to 1997 at various exploitation rates.

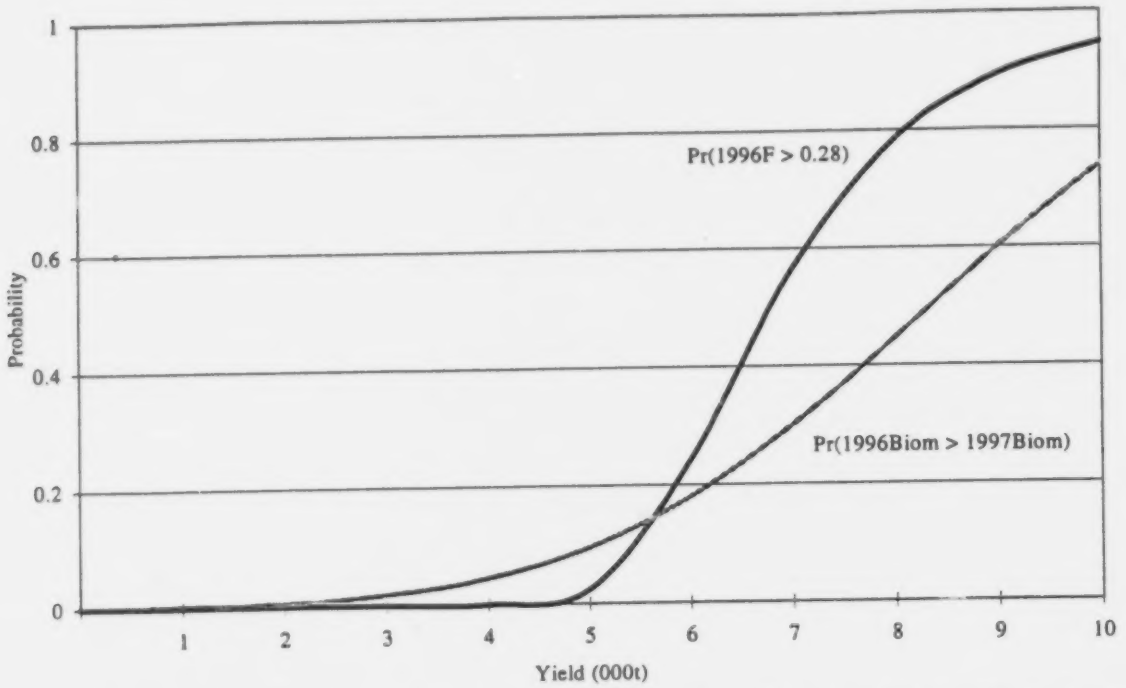


Fig. 23. Probability of the fishing mortality exceeding the $F_{0.1}$ (=0.28) reference level and of the 1997 biomass being less than that of 1996 for various harvest levels.

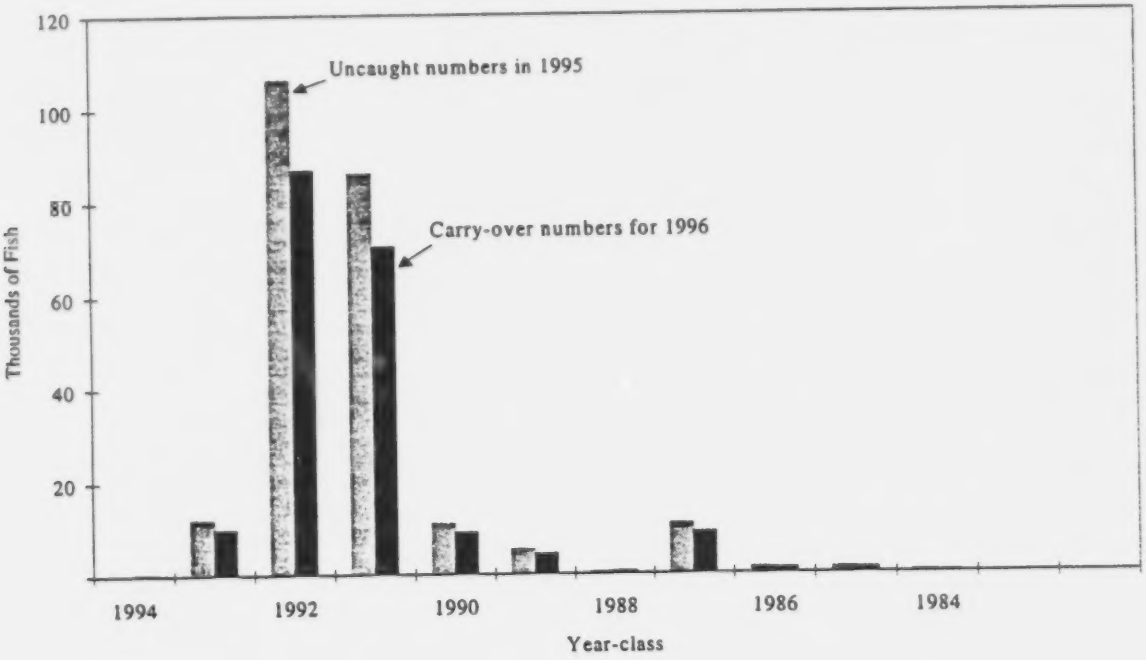


Fig. 24. Decrease of 1995 uncaught numbers to 1996 carry-over numbers due to natural martality.

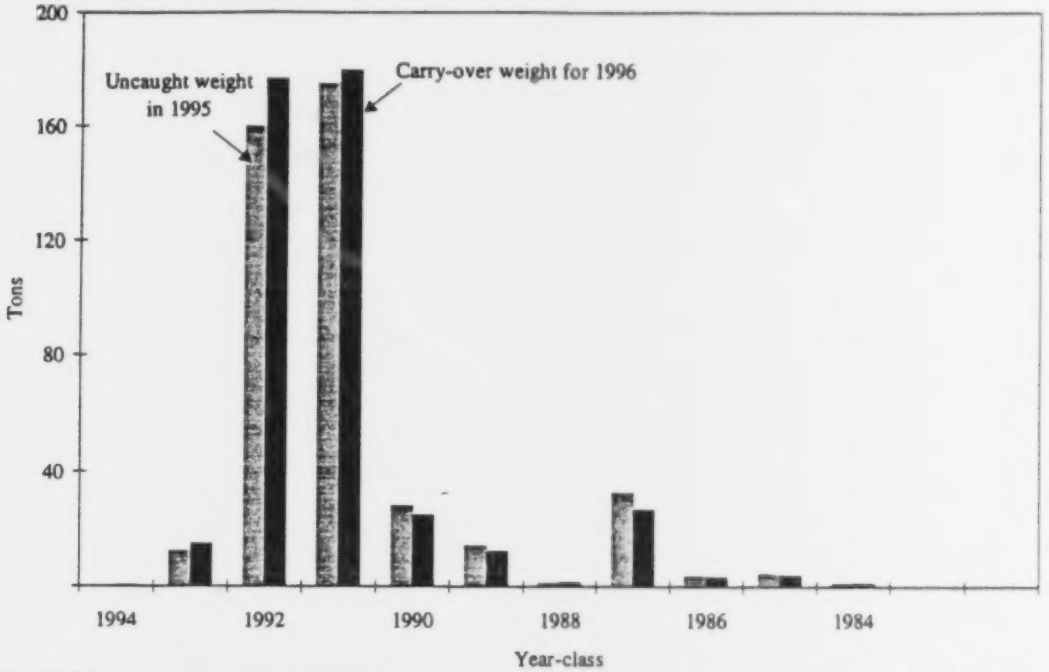


Fig. 25. The maximum carry-over weight for young fast growing year-classes may be greater than the uncaught weight even after accounting for natural mortality.